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I. GENERAL INFORMATION

1. Application

The range-only radar "Kvant" is designed for installation, together with sight ASP-SN or ASP-SND and permissible range computer VRD-2A, on jet fighters.

The range-only radar ensures automatic and continuous determination of distance to the target and of relative rate of approach to the target.

The range radar "Kvant" operates in two modes:

"Mode A" -- firing is done from guns or with unguided rocket projectiles. The range finder feeds continuously to the sight computer voltage proportional to the target gange and relative speed of the target.

"Mode B" -- launching of class air-to-air homing missiles K-13.

For this mode the range radar ensures:

a/ Determination of present range to the target and displaying of such information on the pilot's firing-range indicator UD-1.

b/ Automatic comparison of present range with permissible range of K-13 rocket and providing launching permission signal.

SPN 3 v/ Signalizing the approach of withdrawal-from-attack range.

2. Basic Tactical-Technical Data

a. The range radar "Kvant" determines the distance to aircraft-target in following ranges: from 300 to 3,000 meters for mode "A" and from 800 to 7,000 meters for mode "B"

b. The range radar feeds automatically voltage proportional to the distance to the target to the type ASP-SN sight computer (mode "A") or to the pointer range indicator "UD-1" (mode "B").

v. Range error does not exceed ±15 m for mode "A" and ±100 m for mode "B".

g. Range radar determines the rate of approach to the aircraft-target (relative speed of the target) in a range from +400 m/sec to -100 m/sec, and automatically feeds to the sight computer (mode "A") or to permissible range calculator (mode "B") a voltage proportional to relative velocity. The speed, when closing in on the target, is positive.

d. The error of speed determination does not exceed ± 15 m/sec for mode "A" and ± 85 m/sec for mode "B".

e. The range radar determines the instant for launching rocket K-13 by comparing present-range voltage with permissible-rocket launching range voltage, admitted from permissible range calculator VRD-2A.

zh. Range resolution of range-only radar is not less than 200 m. [P 4]

z. Dead zone of the radar is not greater than 300 m.

i. Directivity pattern of range-only radar at half-power in both planes is equal to 18° + 1° (or -2°) for mode "A" and 6° ± 40' for mode "B".

k. Pulse power is 5 to 7 kw.

ℓ. Duration of high-frequency pulse is 0.5 ± 0.05 microsec.

m. Operating frequency 9370 ± 45 Mc.

n. Pulse repetition rate 800 ± 100 pps.

o. Sensitivity of receiver circuit (mode "A") is 87 db for a range of 2000 m and 68 db for a range of 500 m with reference to 1 milliwatt.

p. Pull-out from attack range is 1000 to 1150 m.

r. Ceiling of the range-only radar - 25000 m.

s. Power consumption of range radar from 115 v, 400 cps power line is 410 va; power consumption in +27v circuit is 25 w when ambient temperature is above 0°C and 130 w when temperature is below 0°C.

t. Weight of the range radar without intermediate cables is 30 kg.

u. The range radar can operate continuously for 6 hrs.

f. Guaranteed service life of range radar is 500 actual flight hours

SPN 5 on an aircraft during a period of 3 years, if all regulation inspections and maintenance work is observed in accordance with operational manual.

3. Range Radar Assembly

The assembly of the range radar "Kvant" designed for aircraft MIG-21P comprises the following units:

a. Combined antenna with waveguide line K-1 - GYa 2.060.054 Sp - 1 piece

b. Receiving-transmitting unit RB6-2M GYa 2.000.024 Sp - 1 piece

v. Range-only radar receiver unit RB6-3 GYa 2.003.002 Sp - 1 piece

g. Power pack unit RB-6-4 GYa 2.087.004 Sp - 1 piece

d. Speed indicator unit RB-6-5 GYa 2.002.005 Sp - 1 piece

e. Control panel K-6 GYa 2.761.031 Sp - 1 piece

zh. Comparator unit K-8 GYa 2.089.012 Sp - 1 piece

z. Intermediate cable KK/21-F/GYa 4.853.165 Sp - 1 piece

i. Coaxial cable GYa.F.850.135 Sp - 2 pieces

k. Control mechanism KPK GYa 2.781.037 Sp - 1 piece

Speed calibrator for 5 assemblies, type "KS-2" GYa 2.761.021.Sp and control instrument KPK GYa 2.761.037Sp are part of the special control-test equipment of the range radar "Kvant."

II. PRINCIPLE OF OPERATION AND INTERACTION OF INDIVIDUAL COMPONENTS OF RANGE RADAR "KVANT"

1. Principle of Operation

The principle of range radar operation is based on illumination of a given space zone by short-duration recurring electromagnetic pulses, and reception of such pulses after reflection from a target located in the zone of illumination.

The range radar "Kvant" determines the distance to the target by automatic measurement of time interval between the initiation of probing pulse and the instant of arrival of pulse reflected from the target, fig. 2.

The range radar "Kvant" is an automatic electronic device which does not require attendance, except for switching-on during take-off and switching-off during landing.

Observation of range radar "Kvant" performance in flight can be carried out by watching an aircraft-target flying in front; after target lock-on by the radar, a green lamp "lock-on" lights on the sight head.

For mode "A" operation, the manual feed of range to the sight is disconnected at this time (handle of gas sector), and the size of outer circle of the vision and target field is now changed only from the range radar.

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For the mode "B", the firing sight is set into position "fixed" ("ne[illegible]"); at this time the illuminated mark occupies a position corresponding to direction of aircraft gun axis, and the pointer indicator UD-1 on the instrument board show automatically the distance between the aircrafts.

Thus, aiming is done at a stationary mark, as on a collimator sight.

SPN 9 Relationship between the distance to the target, the velocity of electromagnetic wave propagation in free space and the time interval from the moment of sending high-frequency probing pulse to the instant of reception of pulse reflected from the target is defined by the formula

$$t = \frac{2D}{S}$$

where: t - time interval for high-frequency pulse to travel to the target and back; 2D - doubled distance to the target, i.e., distance to target and back; S - velocity of electromagnetic wave propagation, which is equal to the speed of light

$$S = 3 \times 10^8 \text{ m/sec}$$

Time measurement is carried out by continuous superposition of the target pulse on the selector pulse, which is generated by the range finder. The delay time of selector pulse is related linearly to voltage applied to the circuit of time modulator, which generates such pulse, i.e.,

$$t_z = K_1 \ (U_o - U_D)$$

where: t_z - delay time of selector pulse

U_D - control voltage

U_o - initial voltage

Due to coincidence of the target pulse and selector pulse,

$t_z = t$, and $K_1(U_o - U_D) = \frac{2D}{s}$ or $U_D = U_o - \frac{2D}{sK_1} = U_o - K_z D$

Thus the voltage controlling the time modulator becomes proportional to the target range. This voltage is fed by the range radar to the sight computer and to indicator UD-1.

The selector pulse consists actually of two pulses, generally called range pulses (see fig. 3). These 0.7 microsec duration pulses, shifted 0.1 microsec with respect to each other, conduct search-scan in absence of reflected pulses, i.e., they are shifted along the whole range of distances from 200 m to 3000 m with a frequency of 1 cps (mode "A") and from 800 m to 7500 m with the same frequency of scan for mode "B".

The shifting takes place from shorter range toward longer. In the event of appearance of a pulse reflected from the target, it comes into coincidence with the range pulse. At this time the lock-on circuit goes into operation and the search-scan is discontinued. The range radar locks on the target and begins to range-track the target by feeding voltage proportional to the range to the sight computer or to the pointer indicator UD-1.

The range radar "Kvant," in addition to range voltage, also supplies voltage proportional to the relative speed of target.

The speed voltage is obtained by differentiating range voltage and its subsequent amplification by a special amplifier located in the speed unit.

The law for range voltage generation:

$$\text{For mode "A"} — U_D = 195 - \frac{D}{20}$$

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For mode "B" - $U_D = 195 - \frac{D}{50}$ [P 11]

where: U_D is voltage in volts

D is range in meters

The law for speed voltage generation:

for mode "A"— $U_{sk} = -0.1V$

for mode "B"— $U_{sk} = -0.04V$

where: U_{sk} - voltage in volts

V - speed in meters per sec.

For an approach the speed is positive.

The peculiarity of the range radar "Kvant" is its ability to operate in two different modes. For this reason the radar antenna consists of two different antennas - of a horn antenna producing a wide 18° + 1° or -2° beam for mode "A", and a reflector antenna producing a narrow 6° ± 40' beam for mode "B".

A switch located in the range radar connects one of the antennas to the receiver-transmitter unit.

The antenna switching is controlled from the aircraft circuit.

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5. Block Diagram of Range Radar

As seem from fig. 4, the range radar "Kvant" consists of antenna unit, receiving-transmitting unit, range-only radar receiver, power supply unit, speed unit, control board, comparator unit, intermediate cable and coaxial cable.

SPN 13 Antenna Assembly Unit - consists of a combination of a horn antenna with dielectric lens and a reflector antenna with horn exiter.

This antenna assembly is designed for highly-directive radiation of high-frequency electromagnetic energy and for reception of signals reflected from a target.

Directivity pattern of the horn antenna while in mode "A" is 18° + 1° or -2° in both planes.

Directivity pattern (or beam width) of reflector antenna while in mode "B" is 6° ± 40' in both planes.

The receiving-transmitting unit forms and radiates powerful high-frequency pulses, automatically adjusts frequency of local oscillator, receives and pre-amplifies reflected signals, switches antenna from transmission to reception and synchronizes the work of range-only receiver unit.

The receiving-transmitting unit consists of a high-frequency, f = 9370 ± ± 45 Mc, magnetron oscillator, a modulator, a sub-modulator, klystron local oscillator, receiving-transmitting chamber with mixer, ATR tube, spark-gap

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discharger, mixing chamber for automatic frequency control (APCh), preamplifier of intermediate frequency |PUPCh|, AFC circuit, high-voltage rectifier, and pre-ionization rectifier with ignition current stabilizer.

SPN 14 The range-only radar receiver unit serves to amplify the IF of reflected pulses, to detect such pulses and to convert them into target video-pulses, to fix the time of arrival of reflected pulses and to form voltage proportional to the distance to the target.

Power supply unit provides stabilized voltage to all units of the range radar. The unit contains a rectifier for +150 v and +200 v, a rectifier for +300 v, a rectifier -150 v, electronic voltage regulator and a reference stabilovolt.

Speed indicator unit serves to determine automatically the relative speed of target, and to supply appropriate voltage to the firing sight and permissible range computer VRD-2A.

Control board serves to facilitate the operation of the range-only radar installed on an aircraft. All controls of the range radar and the control points for checking the performance of the automatic lock-on are located on it.

Comparator unit serves to convert the voltage scale of target present range into a scale corresponding to the scale calibration of the UD-1 pointer range indicator, to compare automatically the voltage of target present range with the voltage of permissible launching range of the rocket, and to send launching permissible signal to the green lamp "launch" installed on the pilot's instrument board, to determine the moment for withdrawal from attack by sending a signal to the red lamp "pull out" installed on the pilot's

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Intermediate Cable Wiring Diagram

(1) Sh-8
Plug Rl4?PK175Shl

Goes to	Function	Term. No.
to Unit No. 5	ground	1
	+ 115 v (com)	2
	~ 115 v (com)	3
	+ 27 v	4
	U_{range} unit 5	5
	speed scale	6
	+ 200 v	7
	lock-on circ.	8
	speed zero	9
	speed zero	10
	tracking	11
	U_{speed}	12
	lock-on sig.	13
	- 150 v	14
		15
	+ 300 v	16
	+ 150 v	17

(2) Sh-3
Plug Rl48PKEShl

Goes to	Function	Term. No.
to Unit No. 6	ground	1
	+ 27 v in.	2
	+ 27 v out.	3
	+ 115 v in. (com)	4
	+ 115 v out. (com)	5
	~ 115 v in.	6
	~ 115 v out.	7
	search freq.	8
	search freq.	9
	+ 150 v out.	10
	+ 150 v in.	11
	+ 200 v	12
	U_{range} A	13
	range zero	14
	range scale	15
	speed scale	16
	speed zero	17
	speed zero	18
	ferrite switch	19
	U_{range} (input)	20
	- 150 v	21
	U_{range}	22
	sensitivity	23
	AFC circuit	24
	ferrite sw. cryst.	25
	mode signal	26
	ferrite switch	27
	ferrite switch	28

(3) Sh-7
Socket R48PK28EG1

Goes to	Function	Term. No.
to External Circuit	ground	1
	altitude sig.	2
	+ 27 v in.	3
	~ 115 v	4
	~ 115 v (com)	5
		6
		7
	input switch	8
	input switch	9
	? input sw.	10
	? input sw.	11
	lock-on sig.	12
	mode signal	13
	VRD supply	14
	VRD supply	15
	VRD output	16
	range instru.	17
	range instru.	18
	U_{speed}	19
	pullout sig.	20
	+ 200 v	21
	U_{range} A	22
	clearing	23
	- 150 v	24
	launch sig.	25
		26
		27
	altitude sig.	28

(4) Sh-5
Socket 2RM24KPN19G1A1

Goes to	Function	Term. No.
to Control	ground	1
	~ 115 v	2
	~ 115 v	3
	U_{speed}	4
	+ 27 v	5
	ferrite sw. crys.	6
	U_{range}	7
	Tk I	8
	Tk II	9
	TM	10
	+ 150 v	11
	launch	12
	- 150 v	13
	meas. ground	14
	+ 200 v	15
	+ 300 v	16
	RRCh (MFC)	17
	RRU (MGC)	18
	calibration	19

(b)

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(5) Sh-2
Socket RG40U17EShl

Goes to	Function	Term. No.
to Unit No. 2	ground	1
	~ 115 v	2
	~ 115 v (com)	3
	+ 27 v	4
	meas. ground	5
	+ 150 v	6
	Tk I	7
		8
		9
	~ 115 v in.	10
		11
	- 150 v	12
	APCh (AFC) amp.	13
	RRCh (MFC)	14
	TM	15
	Tk I	16
	+ 300 v	17

(6) Sh-1
Socket R48PK28Shl

Goes to	Function	Term. No.
to Unit No. 3	ground	1
	+ 27 v	2
	~ 115 v	3
	~ 115 v (com)	4
	+ 300 v	5
	+ 200 v	6
	+ 150 v	7
	- 150 v	8
	U_{range}	9
	tracking	10
		11
	range scale	12
	search freq.	13
	search freq.	14
	UPCh (AFC) shift	15
	lock-on circ.	16
	sensitivity	17
	launch pulse	18
	+ 150 v in.	19
		20
	clearing	21
		22
		23
	range zero	24
	U_{range}, unit 5	25
		26
		27
		28

SPN 15

(7) Sh-4
Socket 2RM30BL132G1A1

Goes to	Function	Term. No.
to Unit No. 8	ground	1
	+ 27 v	2
	+ 300 v	3
	+ 200 v	4
	+ 150 v	5
	supply	6
	supply	7
	VRD output	8
	U_{range} in.	9
	instru. "D"	10
	instru. "D"	11
	U_{speed}	12
	pullout sig.	13
	launch sig.	14
		15
		16
	mode signal	17
		18
	lock-on circ.	19
		20
		21
	altitude sig.	22
	altitude sig.	23
		24
		25
	- 150 v	26
		27
		28
		29
	calibration	30
	~ 115 v	31
	~ 115 v (com)	32

(8) Sh-6
Socket 2RM14KPN4G1A1

Goes to	Function	Term. No.
to Unit No. 1		1
	ferrite switch	2
	ferrite switch	3
	ferrite switch	4

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SPN 16 instrument panel, supplying +28 v stabilized voltage with respect to spec. voltage, to VRD-2A.

Intermediate cable serves to interconnect the units of the range-only radar on an aircraft. Cable configuration and size depends on the deployment of the range/finder on a given aircraft. Schematic lay-out of the intermediate cable for the MIG-21F combat jet is shown in fig. 5.

6. Functional Diagram

On fig. 6 is shown the functional diagram of the range-only radar "Kvant". This diagram shows interaction of individual components of the range radar.

The operational mode of the range radar is different for the search-scan of the target from the tracking of target, when the reflected signal enters the receiver input.

For this reason the description of functional diagram is divided into 2 sections:

a/ Search-scan mode

b/ Tracking mode

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Search-Scan Mode

The submodulator located in the receiving-transmitting unit generates positive voltage pulses with amplitude not less than 150 v, pulse duration of about 1 microsec and repetition rate of 800 pps. These pulses control the discharge tube of the modulator.

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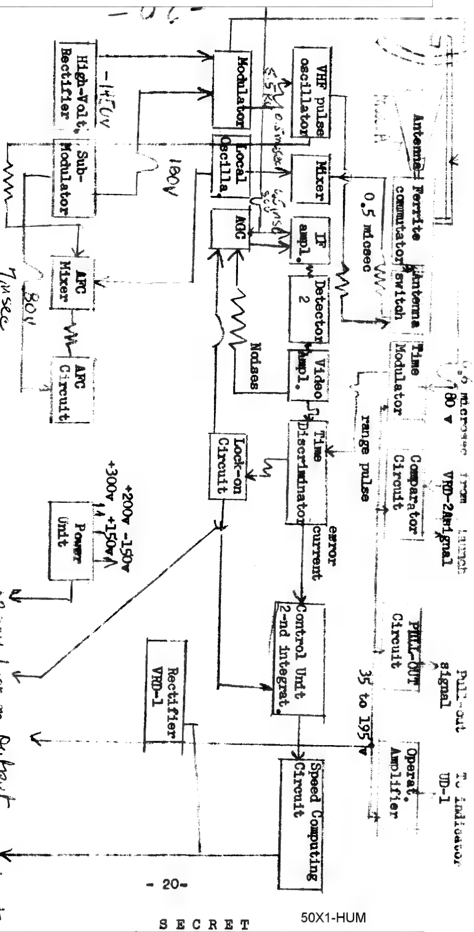

Fig 6. Functional Diagram of Range-Only Radar "Kvant".

The modulating pulses with 5.5 kv amplitude, 0.6 microsec duration and repetition rate of 800 pps are generated in modulator and are fed to the magnetron.

Magnetron oscillator generates pulses of τ = 0.5 microsec duration and power of not less than 5 kw.

The antenna switch disconnects the receiver during the action of probing pulse.

Powerful high-frequency magnetron pulses are admitted through high-frequency channel to ferrite commutator which directs the electromagnetic energy to one of the antennas, depending on the operating mode of range-only radar.

Part of high-frequency energy of the magnetron pulse is admitted to the mixing chamber of AFC. Undamped high-frequency oscillations from klystron local oscillator are also continuously admitted to AFC chamber.

As a result of mixing of two high-frequency oscillations, a pulse is formed at the AFC output with a frequency which is equal to the difference between the klystron and magnetron frequencies.

This pulse is converted by the AFC circuit into the control voltage, [P 19]
which is fed to the klystron local oscillator and maintains klystron frequency above that of the magnetron frequency by a value equal to IF.

Simultaneously with the modulating pulse, a negative synchronizing pulse is fed from modulator to:

a) to IF amplifier and disconnects receiver during the transmission of main probing pulse;

b) to noise AGC and cuts it out for the reception period, thus eliminating the effect of target pulses on performance of the noise AGC

v) to fast saw-tooth forming circuit and triggers it.

The "fast saw-tooth" circuit feeds to the comparator circuit unit RB6-3 a saw-tooth pulses at a rate of 800 pps and of 25 or 50 microsec duration (depending on the mode) and of 150 v amplitude (fig. 7).

In addition, to the comparator curcuit unit RB6-3 is fed a saw-tooth voltage from the "slow saw-tooth" generator, which varies in intensity from 185 to 20 v during a period of .8 to 1.2 sec.

With this gradual decrease of "slow saw-tooth" generator voltage, there occurs greater and greater delay in conduction of comparator diode for each successive period of 800 pps repetition rate.

Thus, to the subsequent circuits of the comparator is admitted a saw-tooth pulse with leading edge lagging more and more behind the transmitter pulse as the sweep generator voltage decreases.

SPN 20 This pulse is amplified and differentiated, and is used to trigger range pulse generator. The latter generates 100-v range pulse of .7 microsec duration which is fed to time disriminator. The time discriminator operates only during coincidence in time of range and target pulses.

As is seen from fig. 7, with gradual decrease in voltage of the "slow saw-tooth", the range pulses traverse the whole working range of search-scanning at a rate of .8 to 1.2 cps.

The noise voltage from receiver output is admitted to noise AVC circuit which develops negative voltage proportional to noise magnitude. This voltage is admitted to IF amplifier, and by varying amplification factor the noise level is maintained constant at the receiver output.

Tracking Mode

Pulses reflected from the target are intercepted by one of the antennas, depending on the mode of operation, and are admitted by high-frequency channel through the ferrite switch to the antenna switch, which prevents the entrance of reflected signal to the magnetron circuit, but admits reflected pulses to the mixing chamber of the receiver.

At the mixing chamber of the receiver the reflected signal frequency is mixed with the local klystron oscillator frequency.

SPN 21 As a result of mixing, a number of frequencies are formed from which the 30 mc IF is separated out at the receiver mixer. Input circuit of IF preamplifier (PUPCh) serves as the load of the receiver mixer.

After passing through the IF preamplifier, the signal reflected from target is admitted to the main IF amplifier. The target signal after second detection and amplification in IF amplifier is admitted to the input of time discriminator through the video amplifier and cathode follower.

Time discriminator forms error current at the instant of coincidence of the target reflected pulse with the range pulse. Such error-current value depends on magnitude and sign of mismatch between range and target pulses. The error signal is admitted to the input control-unit circuit, which is in the form of a double integrator.

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The time discriminator also generates negative pulses which control the automatic lock-on.

At this time the automatic lock-on goes into operation and search-scan generator circuit is transformed into a double integrator and the signal lamp "lock-on" lights up on the sight.

The range-only radar circuit now switches to tracking mode and processes voltages proportional to the target range and relative speed of the target. At the instant of target lock-on and switch-over of "slow saw-tooth" generator, at the output of double integrator remains a voltage corresponding to target range, as it was at the instant the automatic lock-on went into action. This voltage is fed to the comparator unit circuit RB6-3, instead [F 23] of the "slow saw-tooth" generator voltage, and it controls the range-pulse displacement in time.

The error current of time discriminator is continuously admitted to the double integrator until the range pulse comes into balance with the target pulse.

With the disappearance of target signal, the automatic lock-on is released after a delay of 1 to 1.5 sec.

The output range voltage continues to change accordingly with the same law and at the same speed during the delay period as it occurred prior to target disappearance, thus ensuring the "memory" of target speed.

Pulse from the plate of automatic lock-on amplifier is fed to input of AVC circuit. This pulse is amplified and detected, and as a negative dc voltage is fed to IF amplifier, thus changing the receiver amplification which is necessary to avoid overloading receiver stages and to decrease the range error for targets of different intensity.

The performance of noise AVC in both search-scan and tracking modes is identical. Pulse AVC and noise AVC have common output to IF amplifier through cathode follower. When range-only radar "Kvant" locks-on target in mode "B", the range voltage is fed to electronic circuit in unit [illegible]-8 which compares it with permissible range voltage, the latter coming from computer VRD-2A.

By permissible range for rocket launching is understood a maximum dis- [P 24]
tance to the target at which the rocket will necessarily reach the target while the homing system is in operation.

Such a range is defined by the following equation:

$$D_{r\,km} = 3.06 \cdot 10^{-3} \left[\Delta V_{sr} (V_N H) + D \right]$$

The magnitude of permissible range depends on the aircraft altitude (H), air speed of aircraft-carrier (V_N), as well as of magnitude and sign of relative speed (D).

Permissible range becomes greater with the increase in flight altitude (air resistance becomes smaller), with the increase in speed of the carrier (initial speed of rocket), and with increase in relative speed of approach to the target.

The permissible range computer VRD-2A consists of a potentiometric transducer, which is fed with dc voltage from range radar, and which supplies a voltage proportional to permissible range according to the following law:

$$U_{d\text{-}razr} \, |v| = 3.625 \left(D_{rasr} \text{ in km} \right)$$

The VRD-2A solves the equation:

$$\Delta \ Vsr = \int \left(\frac{V_N}{H} \right)$$

and the obtained voltage is added to the relative speed voltage which was admitted to range radar "Kvant" according to the following law:

$$U_d \ (v) = -0.04D \ \left(\frac{m}{sec} \right)$$

[P 25]

U_d is positive during approach.

Speed range: from -100 m sec to +400 m sec, which corresponds to voltage variation from -4 v to +16 v.

Total voltage from the slider of VRD-2A potentiometer is admitted to electronic circuit of the comparator unit K-8. When the present range to target becomes equal or smaller than the rocket-launching permissible range, then the comparator circuit operates and on the pilot's instrument board lights on the green lamp "launch." From this instant the pilot may launch the K-13 rocket if all other required conditions are fulfilled.

Present range voltage is also admitted to a special circuit which, upon approaching a range of 1000 m, lights on a red signal lamp "pull-out," thus warning the pilot of the danger from further approach to the target. Such further approach may result in collision with the target or damage from the fragments of the rocket.

On the pilot's instrument board is located the pointer indicator UD-1 of range to the target, which is in the form of a voltmeter graduated directly in km, from 0 to 8 km. This range indicator is fed with power through operational amplifier of K-8 unit.

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THE ANTENNA WAVEGUIDE ASSEMBLY [P 26]

7. Application

The antenna waveguide unit is designed for transmitting high-frequency power from the oscillator to the antenna, the radiation of this energy into space within the limits of definate spatial angle, the reception of signals reflected from the target and their transmission to the receiver.

8. The basic tactical-technical data of the antenna waveguide channel

1. The width of the directivity pattern in the wide beam mode/mode "A"/ is $18 \pm \frac{1^\circ}{2^\circ}$ in planes E and H, and is $6^\circ \pm 40'$ in the narrow beam mode/mode "B"/ in both planes.

2. The side lobes do not exceed 5% of the maximum in both modes.

3. The gain factor of the antenna is equal to 85 in mode "A" and 550 in mode "B".

4. The standing wave ratio of the antenna waveguide unit does not exceed 1.5 at frequency range of 9370±45 MC.

The antenna-waveguide unit of the "KVANT" range-finding radar consists of two structurally combined antennas and a waveguide channel with a ferrite commutator, which provides for switching the operating modes of the station/wide and narrow beam/.

The gain factor is determined by comparing the antenna [P 27] being tested with the standard one, the gain factor of which is known from the following formula.

$$G_{isp} = G_{et} \times \frac{P_{isp}}{P_{et}}$$, where

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G isp is gain factor of the antenna being tested.

G et is the gain factor of the standard antenna.

P isp is the power being received by the antenna being tested.

P et is the power being received by the standard antenna.

The gain factor of the antenna for the "KVANT" range finding radar is equal to 85 in the wide beam /mode "A"/ and 550 in the narrow beam /mode "B"/.

For a more complete transmission of the transmitter power to the antenna, matching of all the high frequency channels is of great importance. The matching of the high frequency channel is characterized by the value of the standing-wave ratio.

In an ideal case, during the absence reflection, a traveling-wave mode is established in the high-frequency channel /during which SWR=1/. In the presence of reflection a standing wave appears in the channel. Such standing wave is formed as a result of the composition of incident and reflected waves.

The standing wave ratio is defined as the ratio of the maximum value of voltage in the line to the minimum

$$KSB\ (SWR)\ \frac{U\ max\ C.}{U\ min}$$

the better the matching, the smaller the difference between U maximum and U minimum , and consequently the smaller the magnitude of SWR.

The standing wave ratio in the antenna-waveguide unit of the "KVANT" [P 28]
range-finding radar does not exceed 1.5 in both modes.

The wide directivety pattern of the "KVANT" range finding radar /mode

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"A"/is radiated by the horn antenna. The directivity pattern of the horn antenna depends on the dimensions of the horn, its length and size of the aperture of the output opening.

In the horn antenna a dielectric lens is intalled in the aperture of the horn. The dielectric lens serves to equalize the field phase in the horn aperture, which, in turn, leads to higher gain factor and lower intensity of the side lobes of the directivity pattern. The side lobes are responsible for useless diffusion of a part of the radiated power and for lowering the noiseproof feature of the station. The electrical field of the horn has vertical polarization. The horn antenna is connected to the waveguide through a coupling transformer with a 12 x 23 mm cross section, and is tuned in designated range of frequencies with the aid of a matching stub.

The air-tightness of the antenna is achieved with the aid of polystyrole foam bushing, which is pasted to the mouth of the horn with epoxy resin.

The narrow directivity pattern /mode "B"/of the "KVANT" range finding radar is radiated by the reflector antenna.

The reflector antenna is a radiating device in which the electromagnetic waves from the primary exciter is directed by the reflector into space within the limits of a certain space angle, depending on the diameter of the reflector.

The antenna reflector is a circular parabola with a diameter of 360 mm and a focal distance of 235 mm.. The focal distance was selected in such a manner that the primary radiating element of the reflector antenna

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would in a least degree overshadow the radiation from the horn antenna located behind the reflector /fig. 87.

The primary exciter of the antenna is a horn radiator. The size of the horn radiator is selected in such a manner that the radiation directivety pattern formed by it would have in the direction of the edge of the reflector, considering the spatial attenuation, an intensity 0.1-0.1 times of the maximum power, thus the power density at the edge of the parabolloid becomes 6 to 10 times smaller than at its central part.

Under such a condition, the optimum value of the reflector surface utilization ratio, which is necessary for obtaining the maximum gain factor of the antenna for a given diameter of the reflector, is provided. The polarization of the electrical field of the antenna is horizontal.

The horn exciter is off the focus by 6°. This makes it possible, firstly, to reduce the effect of the reflector surface on matching the waveguide channel and, secondly, to remove the exciter of the reflector antenna from the radiation zone of the horn antenna.

Since part of the energy of the horn strikes the exciter, is reflected from it, and during the second reflection from the reflector it narrows the [P 30] radiation directivety pattern of the horn antenna. A metal grid made of vertically arranged wires is installed in the aperture of the horn exciter /fig. 8/.

Such a grid is transparent to the electrical field with horizontal polarization, since the vector of the electrical field is perpendicular to the direction of the wires. For the electrical field with vertical polarization, the vector of the electrical field is parallel to the

direction of the wires, consequently, for such a field the grid is equivalent to a metal screen which completely reflects the electromagnetic field. The grid in the aperture of the exciter is located in such a manner that the energy of the horn antenna, the electrical field of which has vertical polarization, will be dispersed by reflection from the grid.

The wires of the metal grid of the exciter are fastened to a bushing made of foam polystyrole. The bushing is pasted to the mouth of the horn exciter with epoxy resin, thus forming air-tightness of the high-frequency channel.

The horn and reflector antenna are fastened to a common mounting by a cast magnesium alloy bracket, while the horn antenna is located behind the central part of the reflector antenna. For this reason, the latter is made in the form of a metal grid with horizontal wires which makes it transparent to the energy radiated by the horn antenna. [P 32]

The combined antenna is fastened to the airplane with the aid of four bolts, which are mounted from the side of the reflector, through special hole to a cast bracket and auxiliary fasteners, provided on the airplane.

9. Waveguide Channel

Block diagram of waveguide channel is shown on fig. 9.

The waveguide channel is built with rectangular aluminum waveguide of 23 x 10 mm cross section, except for ferrite commutator.

High-frequency admitted to the waveguide channel from receiving-transmitting unit (unit RB6-2M) is fed to the ferrite commutator, which in turn directs it into one of the antennas depending on mode of radar operation.

10. Description of Ferrite Commutator

The ferrite commutator switches-on the two antennas alternately, thus radiating different directivity patterns.

The polarization plane rotator and a tee form part of the commutator. (fig. 10).

Ferrite commutator operation is based on the principle of polarization plane rotation.

The ferrite stub, located in transverse magnetic field, rotates polarization plane of electromagnetic wave that passes through it. [P 34]

Ferrite polarization-plane rotator is in the form of a square 21 x 21 mm waveguide section, inside of which in a fluoroplastic insert is mounted grade M-77 ferrite stub of the following size:

d=6.7 mm 1=70 mm

Electromagnet winding of 3,000 turns from .2mm PEV wire is placed outside the square waveguide.

w=3,000 turns

One end of the square waveguide polarization rotator is terminated by a quarter-wave transformer, which is needed for transition from the 21 x 21 mm waveguide to 23 x 10 mm waveguide.

To the other end of the polarization rotator is connected a tee, the outlets of which make 90° with each other (see fig. 10)

For mode "A", a current of the order of 50 milliamp passes through the electromagnet winding. Such current ensures polarization-plane rotation by 90°, i.e., the passage of electromagnetic energy to channel I.

For mode "B" a current of the order of 5 milliamp, need to remove residual magnetism, is passed through the electromagnet winding. Such residual magnetism originates in the ferrite stub during operation in mode "A". Now the electromagnetic energy is directed into channel II. Current direction in the ferrite-commutator winding in mode "B" is opposite to that for mode "A".

SPN 36 Electromagnet current switching is effected by R6-3 relay, located in unit K-6, which is actuated by the mode signal. To ensure operation at high altitude, the waveguide channel is made tight with the aid of rubber gasgets.

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IV. RECEIVING-TRANSMITTING UNIT

11. Application

The RB6-2M receiving-transmitting unit goes into the makeup of the [P 36] "KVANT" airplane radar range finder and is designed for generating powerful high frequency pulses, switching of the antenna from transmission to reception, reception of the signals reflected from the target and their preamplification.

In addition, the receiving-transmitting unit performs automatic frequency control of the local oscillator and generates pulses, which synchronize the operation of the entire station.

12. Make up of the unit

The receiving and transmitting unit consists of the following elements:

a) submodulator;

b) Modulator;

v) magnetron oscillator;

g) antenna switch;

d) mixer of the receiver;

e) mixer for the AFCh (automatic frequency control);

zh) klystron oscillator;

z) preamplifier for intermediate frequency /PUPCh/;

i) high-voltage rectifier;

k) rectifier for the pre-ionizer; [P 37]

l) systems for automatic frequency control of the klystron oscillator /APCh/.

13. The basic tactical-technical data of the unit

The receiving-transmitting unit has the following basic parameters:

a) pulse power of high frequency oscillations

$$P_{imp} \geq 5 \text{ kw}$$

b) the frequency of high frequency oscillations in a range of

$$9370 \pm 45 \text{ Mc}$$

v) duration of modulating pulse

$$\tau_{imp.} = 0.5 \pm 0.05 \text{ microsec}$$

g) the band width of high frequency oscillations at the base $\Delta f \leq 6$ Mc

d) pulse repetition rate

$$F_n = 800 \pm 100 \text{ pps}$$

e) Synchronization-pulse amplitude is not less than 80 v.

zh) The average current of the magnetron is equal to [illegible].9 + 0.[illegible] (?)

z) The crystal current of the receiver channel is 0.2 to 0.8 [illegible]

i) The crystal current of the APCh (AFC) channel is 0.4 to 2.[illegible] ma.

k) The ignitor firing current of the ATR tube is 70 to 95 microamp

l) The average intermediate frequency PUBCh is 30 ± 0.5 Mc

m) Overall dimensions of the unit are:

D = 240 mm

L = 388 mm

n) the weight of the unit does not exceed 12.1 kg.

o) The unit operates normally:

a/ during a temperature change of the surrounding atmosphere from + 50 C to -60 C.

b/ after remaining 48 hours in an atmosphere with a relative humidity of 95-98% at a temperature of ±20°±5°C.

v/ at altitude of up to 25,000 meters, [that is at an atmospheric pressure of up to 18.6 mm Hg.]

14. Description of Unit Operation According to the Functional Diagram

[Fig. 11]

Blocking oscillator of the submodulator utilizes the left half of the L2-3(6NIP) dual triode; it generates positive voltage pulses of 220 v amplitude and 5 to 8 microsec duration with repetition rate of 800 pps. These pulses passing through the cathode follower, which utilizes the right half of the dual triode L2-3(6NIP), control the performance of the modulator discharge tube.

Pulses from the blocking oscillator L2-3 are also admitted through the cathode follower L2-4(6N3P) to the AFC system, where they are used for manipulation (modulation) of the screen grid of the pentode L2-18(6NIP).

The modulating pulses of 5.5 kv amplitude, 0.65 microsec duration and repetition rate 800 pps are formed in the modulator assembled as a circuit with artificial pulse shaping line and hydrogen thyrotron L2-7 (TGI-1-35-3), the latter acting as a discharger, and are then fed to the magnetron L2-9 (MI-158)

Magnetron oscillator generates pulses of 0.5 microsec duration and not less than 5 kw power. [P 39]

Powerful high-frequency pulses from magnetron oscillator are admitted to antenna and are then irradiated into space. Due to the presence of antenna switch in form of a RR-21(L2-12) ATR tube, the receiver becomes disconnected during the transmission of main pulse.

Negative synchronizing pulse with amplitude of 80 v is also taken from the modulator which is fed to IF amplifier for disconnecting the receiver during transmission of main pulse, for disconnecting the noise AVC circuit during reception and for triggering "fast saw-tooth" multivibrator located in the range unit.

Part of the energy of the high-frequency pulse from the magnetron oscillator is admitted through attenuator to the mixing chamber of AFC, where the crystal detector D2-1(D2-2) acts as a mixer. To the AFC mixing chamber are also admitted continuously high-frequency oscillations from klystron oscillator L2-11(K-27).

As a result of mixing of two high-frequency oscillations, at the output of the AFC is formed a pulse having a frequency equal to the difference between the frequency of klystron local oscillator and the frequency of magnetron oscillator.

This pulse is amplified by two IF stages of the AFC circuit assembled with diodes (L2-17,L2-18), and is then admitted to the disciminator circuit [P 40]
incorporating the dual diode L2-19(6Kh2P). Detected pulses from the discriminator output are fed to the two-stage pulse amplifier incorporating dual triode D2-20/6N3P/; here they are amplified and fed to the control tube, i.e. the right half of tube L2-21(6N2P), where second detection of the AFC pulse takes place.

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Negative voltage from L2-21 tube is fed to the repeller electrode of the klystron.

If the fluctuation of IF exceeds the klystron adjustment limits, then the blocking oscillator pulses from left half of L2-21(6N2P) tube are fed to right half of L2-20(6N3P) tube, thus replacing the pulses arriving from the discriminator. The AFC circuit forms control voltage which maintains the klystron frequency at a voltage that is 30 Mc higher than the magnetron frequency.

During reception, the pulses reflected from target are admitted into main waveguide through the ATR tube L2-12(RR-21) through the mixing chamber of the receiver, where crystal diode type D4056, D4056A(D2-3, D2-4) act as mixers. To the mixing chamber of the receiver are also admitted continuously oscillations from klystron local oscillator. A number of frequencies are formed after mixing, from which the 30 Mc IF if separated out on the load of the receiver mixer (input circuit of IF preamplifier).

After passing all stages of the IF preamplifier, assembed with L2-1, L2-2(6Zh1B) tubes, the amplified signals are fed to the input of main IF amplifier of the range unit. [P 42]

High-voltage rectifier assembled with L2-6, L2-5(6S7B) tubes supplies power to modulator tube L2-7(TGI-1-35/3) at a voltage of -1450 v.

Firing rectifier is assembled with L2-10(Tkh-2) L2-15(SGSB) and L2-16 (6S7B) tubes and it feeds power to discharge tube D2-12(RR-21) at a voltage of -750 v, which accelerates firing of the discharge tube during the operation of the unit during its operation of transmission.

SPN 42

15. Description of the operation of the unit according to the schematic diagram (Low frequency unit)

a) Submodulator (fig. 12)

The operation of the modulator is controlled by a submodulator in which voltage pulses of the required amplitude, duration, shape, and repetition rate are formed.

The submodulator comprises a double triode type 6N1P (L2-3) and consists of two stages: a blocking oscillator with self-excitation which occupies the left half of the tube, and a cathode repeater which occupies the right half of the tube.

The pulse from the blocking oscillator is used for manipulation of the AFC system for the emission time of the main pulse.

In order to eliminate the effect of the submodulator on the AFC circuit, a trigger pulse is sent through the cathode repeater L2-4 (6N3P).

SPN 44

b) Blocking oscillator (fig. 13)

The blocking oscillator or pulse generator with transformer coupling is a single-tube self-oscillating system of the relaxation type with strong positive feedback, making it possible to generate short pulses, under certain conditions, which are close to square pulses in shape (fig. 14).

We will begin our examination of the operation of the blocking oscillator from that moment t_0 when the left half of tube L2-3 (6N1P) is blocked due to the voltage drop across resistor R2-10, which is caused by a discharge of capacitor C2-14; the latter was charged to a voltage U_{st} with the polarity shown in figure 15.

Consequently, at this moment the voltage U_d between the grid and the cathode will be $U_d = U_{st}$.

Discharge of the capacitor occurs exponentially with a time constant equal to the product of capacitor C2-14 and resistor R2-10. We will disregard the voltage drop in the secondary winding of the transformer since its resistance for the discharge current is very small.

At the moment t_1 there is a point when the voltage in the grid reaches the value E_{do}, after which the tube opens and the anode current i_a, which will pass through the primary winding of the transformer, begins to build up (fig. 15).

A voltage U_2 will be induced in the secondary grid winding. The ends of the secondary winding are connected in such a manner that
SPN 45 the voltage in the grid increases as the anode current increases. This voltage has positive polarity relative to the cathode. This voltage increase in the control grid of the tube of the blocking oscillator causes an even greater increase in the anode current. In addition, there will occur a decrease in the voltage of the anode of the tube due to the increased voltage drop in the primary winding of the transformer.

The increase in anode current causes a further increase in voltage in the control grid of the tube, and this, in turn, causes an even greater increase in anode current, etc. This process of avalanche-type build-up of anode current is called a direct blocking-process.

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Naturally the anode current cannot build up infinitely since it is limited by the characteristic of the tube.

It should be noted that in the beginning, the rate of voltage build-up in the grid increases.

The increase in grid voltage is linked to a corresponding decrease in voltage in the anode of the tube, which becomes less than the voltage in the grid of the tube. This situation gradually moves the operating point of the tube toward that region of the tube characteristic where, because of the decrease in steepness of the anode current characteristic and the increase in steepness of the grid current characteristic, the necessary self-oscillating conditions for the existence of the blocking process no longer exist.

SPN 47 As a result of this there appear forces which lead to a decrease in the rate of build-up of voltage U_d in the grid, although voltage U_d itself continues to increase. With the increase in voltage in the grid, the steepness of the characteristic assumes smaller values and, consequently, the forces causing the decrease in the rate of build-up of the voltage increase. It is therefore natural that finally, at a particular moment t_3 very close to the moment t_2, the voltage at the grid reaches a maximum $U_{d\ max}$, after which there follows a stage of comparatively slow change in the voltage U_d at the grid (the flat part of the pulse) as well as all remaining voltages and currents.

At the onset of this stage the voltage at the grid begins to decrease rather slowly; however, this decrease does not at first cause a noticeable weakening in the anode current due to the small value of the steepness of the tube characteristic in this region. Since in this stage $U_d > 0$, and the voltage at the anode is sufficiently small, a rather large grid current commensurate with the anode current passes through the tube. As a result of this current, capacitor C2-14 charges, leading to an increase in voltage U_c. With a decrease in voltage at the grid, the operating point of the tube gradually returns to the region of the characteristic in which the steepness assumes greater values.

At a certain moment t_2, the steepness of the characteristic reaches a value at which the condition for existence of the blocking effect is again satisfied. The decrease in voltage at the grid begins to cause a more noticeable decrease in the anode current of the tube,
SPN 48 which leads to a voltage decrease in the windings of the transformer. As a result of the decrease in U_2 there occurs a further more intensive decrease in the voltage U_d at the grid of the tube; this causes a still greater decrease in the anode current and, in this manner, a blocking

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effect phenomenon similar to the one described above but acting in the opposite direction originates. This "reverse" blocking effect leads to a sharp drop in voltage at the grid of the tube and a rapid blocking of of the oscillator tube.

At the moment the tube is blocked, short-duration emf's of rather high value and opposite polarity, which rapidly drop to zero, are induced in the transformer windings. After blocking of the oscillator there begins a stage of slow discharge of capacitor C2-14 in the grid circuit; this is the point at which we began our examination of processes in the blocking oscillator.

The duration of generated pulses is determined by the parameters of the grid circuit of the tube and the parameters of the pulse transformer. The pulse repetition rate is determined basically by the time constant of the discharge circuit of capacitor C2-14. The pulse repetition rate may be regulated by changing the value of resistor R2-10. The output voltage of the blocking oscillator is taken from an auxilliary winding of the pulse transformer, applied to the grid of the cathode follower (the right half of tube L2-3), and represents positive pulses with an amplitude of 220 v, a duration of 5 to 8 microseconds, and a repetition rate of 300 pps.

SPN 50 Resistor R2-13 is connected in parallel with the output winding of the pulse transformer and forms the ballast load of the winding.

A positive pulse for triggering the AFC system is taken from this winding of the pulse transformer. The trigger pulse is applied to triode L2-4 (6N3P) which is introduced into the circuit for the purpose of decoupling the input circuits of the AFC system and the modulator; the triode also plays the role of a limiter.

In the cathode of L2-4 (6N3P) is the divider R2-20, R2-44 from which the trigger pulse passes through the coupling capacitor C2-34 to the screen grid of tube L2-18 (6Zh1P) of the second rf amplification stage of the AFC system. Figure 14 shows the pulse at the output of the blocking oscillator.

In order to decrease the influence of the blocking oscillator on the other circuits of the radar, a decoupling filter consisting of resistor R2-9 and capacitor C2-13 is connected to the oscillator anode circuit.

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v) The cathode follower

Positive pulses from the blocking oscillator are taken from the auxilliary winding of the pulse transformer and applied to the grid of the cathode follower (fig. 16) in order to avoid the effect of the modulator on the blocking oscillator of the submodulator and for the purpose of matching the anode resistance of the load and the output resistance of the blocking oscillator.

The load resistor R2-12 is selected so that the amplitude of the derived pulse will be no less than 150 v. Figure 17 shows the pulse
SPN 53 at the output of the cathode follower.

g) The modulator

The modulator of the transmitter is based on a circuit with an artificial pulse-forming line LF2-1 which discharges through the thyratron type TGI-1-35/3. The circuit of the modulator is given in figure 18.

Operation of the modulator may be divided into two stages: the recharging stage of the pulse-forming line, and the resonance recharging stage of the line.

During pulse recharging of the line a negative square pulse with an amplitude of 5,500 v is formed in the secondary winding of the pulse transformer and is applied to the magnetron, which forms the load of the modulator.

For an explanation of the principle of operation of the modulator we will convert the modulator circuit to an equivalent circuit (fig. 19).

A negative voltage of -1,450 v is applied to the cathode of the thyratron from the high-voltage rectifier, which comprises tubes 1Kh-2 (L2-5, L2-6).

At the moment a positive trigger pulse from the submodulator arrives, the thyratron is fired by the -1,450 v source and the pulse-forming line recharges in such a manner that, toward the end of the recharging period, the voltage in the line is equal in magnitude to the voltage at the cathode of the thyratron; that is, it is equal to the voltage of the -1,450 v power supply. When the recharging period terminates, the thyratron is extinguished and the pulse-forming line slowly begins to recharge through the following circuit: the pulse-

SPN 54 forming line, the primary winding of the pulse transformer, and choke Dr2-1 (fig. 20).

A diagram of the discharge circuit of the line is shown in figure 21.

The recharge circuit represents an oscillatory circuit whose capacitance is the total capacitance of the pulse-forming line LF2-1 and whose inductance L is the inductance of the choke Dr2-1 (the inductances of the pulse-forming line and the primary winding of the pulse transformer may be disregarded because of their small value in comparison with that of choke Dr2-1). Thus, the parameters of the oscillatory circuit are selected so that the period of natural oscillations is equal to $T = \frac{2}{F_s}$, where F_s is the pulse repetition rate of the submodulator.

Figure 22 shows a graph of the voltage change in the pulse-forming line. It can be seen that, for a period of natural oscillations equal to T, the trigger pulse of the submodulator arrives at the moment when the voltage in the pulse-forming line, as a result of the resonance recharging of the line, becomes equal to + 1,450 v. With the arrival of the positive pulse, the thyratron fires and the period of pulse recharging begins.

The trigger pulse to the grid of the thyratron passes through a coupling capacitor C2-16 and a resistor R2-15 which serves as a limiter of the thyratron grid currents.

Resistor R2-14 is a leak resistance in the control grid circuit of the thyratron.

SPN 56 Figure 21 shows an equivalent circuit of the pulse recharge system of the line. It may be seen from the picture that at the moment the thyratron fires there are two series-connected emf's in the recharge circuit -- the emf of the battery E and the emf of the pulse-forming line, which is charged to the voltage of the power supply. These emf's are loaded with two resistances -- the characteristic impedance of the line and the resistance of the load, which is equal to the characteristic impedance of the line. Thus, a voltage approximately equal to twice the voltage of the power supply is applied to the anode of the thyratron relative to the cathode. In view of the equality of the characteristic impedances of the pulse-forming line and the load, this voltage will be, in the ideal case, equally distributed between them, and in this manner a voltage will appear at the load which will be equal to the voltage of the power supply.

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From the theory of infinite lines it is known that a line loaded by a resistance forms within it a square voltage pulse, the duration of which is determined by the recharge time of the line which, in turn, is determined by the parameters of the artificial long line. Thus, the best shape of the pulse and the greatest efficiency will be obtained by completely matching the characteristic impedance of the line with the load resistance. (The resistance of the fired thyratron may be disregarded due to its small size).

The modulator of the unit uses a two-element artificial line of the link type. Its parameters are:

SPN 58

a) total inductance L = 16.5 microhenries
b) total capacitance C = 4,300 picofarads
c) characteristic impedance ρ = 68 ohms
d) shaped pulse duration (for a level of 0.5) τ = 0.65 microsecond

As was noted above, the magnetron is the load of the modulator. But since its resistance for the given operating conditions differs sharply from the characteristic impedance of the line and is equal to 1,300 ohms, direct connection of the magnetron to the modulator would lead to mismatching of the line, a significant decrease in efficiency, and to sharp distortion of the shape of the modulating pulse.

In order to avoid this, the magnetron is connected to the modulator through the pulse transformer Tr2-5, which makes it possible to match the characteristic impedance of the pulse-forming line with the resistance of the magnetron. In this case the resistance of the primary winding of pulse transformer Tr2-5, taking into account the total resistances of its auxilliary windings, is equal to 68 ohms; that is, the pulse-forming line is loaded by a resistance equal to its characteristic impedance.

In addition to performing this matching function, the pulse transformer is used to obtain a pulse in the secondary winding having an amplitude several times greater than the voltage pulse in the primary winding (on the order of 5,300 ÷ 5,700 v). This makes it possible to use the sources of lesser voltage and, consequently, also simplifies high-voltage protection of the circuit of the unit.

SPN 60 The pulse transformer has a double secondary winding through which the filament voltage passes to the magnetron. Such a filament supply circuit makes it possible to use the transformer as a filament-supply transformer under a relatively low voltage. In order to create a closed circuit for the variable component of the magnetron anode cur-

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rent, leads 3 and 5 of the secondary winding of the pulse transformer are blocked by capacitors C2-21, C2-22, C2-23, and C2-24, forming a so-called filament supply circuit with a middle grounding point (fig. 23).

As a result of the fact that the moment of firing of the thyratron relative to the pulse of the submodulator blocking oscillator fluctuates from pulse to pulse within the limits of 0.03 to 0.04 microseconds, it is impossible to provide synchronous operation of the entire station from the pulses of the submodulator; therefore, a pulse, in addition to the modulating pulse of the modulator, is taken from auxilliary winding 7-8 of the pulse transformer for the purpose of synchronizing the operation of the station. This pulse has a duration of 0.6 microseconds and an amplitude of 80 volts. (See fig. 18). In order to avoid parasitic oscillations, the winding is shunted by resistor R2-26. To eliminate "noise induction", the trigger pulse is picked up with the aid of shielded conductors.

The trigger pulse is taken from winding 7-8 of transformer Tr2-5 (fig. 18) and is fed through the right half of tube L2-4 to the ranging unit of the station for synchronization. Load resistor R2-41 is specially selected to match the amplitude of the trigger pulse.

SPN 61 A 3 kv spark discharger L2-8 R-1 is connected in parallel with the primary winding of the pulse transformer. In the case of various malfunctions, such as in operating the modulator with no load (the magnetron not generating), the spark discharger does not permit the voltage in the pulse-forming line to exceed 3 kv.

A small inductance L2-8 (5 microhenries) is connected to the anode circuit of the thyratron for the purpose of improving the operating conditions of the thyratron.

In parallel with the thyratron filament is capacitor C2-17, which serves to eliminate stray pulses from the filament and the filament winding of the transformer.

The modulator circuit as used in the given unit has substantial advantages over other circuits with artificial pulse-forming lines. This may be seen in the fact that the voltage at the high-voltage points of the modulator does not exceed the voltage of the power supply (1,450 v), while the amplitude of the pulse at the load is equal to the voltage of the power supply.

In other circuits the voltage in the line and at the anode of the thyratron is twice the voltage of the power supply (with respect to "ground"), while the pulse amplitude at the load is equal to the value of the power supply voltage.

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d) High-voltage rectifier

The high-voltage rectifier operates in a voltage doubling circuit with two thyratrons type TKh-2 (L2-5, L2-6).

A schematic diagram of the rectifier is given in figure 24.

The rectifier and voltage doubling circuit consists of two series-connected single-phase rectifiers operating with a capacitive load.

One of the single-phase rectifiers is formed by the secondary winding of transformer Tr2-4, thyratron L2-5, and capacitor C2-18a; the other is formed by the secondary winding of transformer Tr2-4, thyratron L2-6, and capacitor C2-18b.

Thus, for one half-period the voltage of the secondary winding charges capacitor C2-18a through thyratron L2-5, and for the other — capacitor C2-18b through thyratron L2-6.

The total voltage with respect to the frame which is taken from point "a" is equal to - 1,450 v.

The modulator thyratron is the load of the rectifier.

Divider resistors R2-22, R2-23, and R2-24 (1 Megohm each) are connected in parallel with capacitor C2-18. The purpose of the divider is to create a capacitor discharge circuit; that is, it is the ballast load of the rectifier.

These resistors protect the capacitor from disruption during no-load operation of the rectifier.

SPN 64 To provide step regulation of voltage at the output of the high-voltage rectifier, the primary winding of the transformer is made with taps. By switching the tap, which is connected to a ~ 115 v, 400 cps network, it is possible to change the voltage in the secondary winding, increasing it or decreasing it relative to the position of the switch by changing the transformation ratio.

ye) Firing rectifier for ATR tube

The firing rectifier for the ATR tube is tube TKh2 (L2-10) (fig. 25).

A voltage of - 750 v is applied to the anode of TKh2 from the

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secondary winding of transformer Tr2-10.

The rectifier operates in a single half-period rectification circuit.

The rectified voltage is taken from capacitor C2-31. This voltage is applied to the firing current stabilizer of the ATR tube, which comprises tubes L2-15 (SG-5B) and L2-16 (6S7B).

The stabilizer circuit maintains the load current during changes in input voltage as well as during changes in load resistance.

Triode 6S7B is used as a control tube in the stabilizer. In order to compensate for large negative bias formed by a voltage drop at the cathode resistor R2-39, a constant reference voltage is applied to the control grid circuit of the control tube (tube L2-15 (SG5B) is used as the source of the reference voltage). This voltage acts counter to the voltage in resistor R2-39. The voltage is taken from potentiometer
SPN 66 R2-78. By using the potentiometer to regulate the bias in the control grid, it is easy to establish the required load current. Resistor R2-39, which is connected to the cathode circuit of the control tube, represents a current feedback element with which current stabilization is achieved during changes in load resistance. Let us assume that the load resistance increases for some reason. This causes a decrease in the anode current and a voltage drop in resistor R2-39, and, consequently, a decrease in negative bias at the grid of control tube L2-16. The resistance of tube L2-16 for a constant current will drop and the load current will remain almost unchanged. With a decrease in load resistance the bias at the grid of tube L2-16 increases, the resistance of tube L2-16 increases, and the load current also remains practically unchanged.

SPN 67

16. High-Frequency Device of the Receiver-Transmitter Unit

a) Function

The high-frequency device of the receiver-transmitter unit is designed for generating powerful high-frequency pulses, for transmitting the energy of these pulses to the antenna-waveguide system, for switching the antenna-waveguide system from transmit to receive, and for converting the received high-frequency signals to i-f signals.

The high-frequency device includes the following elements:

high-frequency magnetron oscillator;
antenna switch;
receiver mixer;
AFC mixer; and
klystron oscillator.

b) The high-frequency device

In order to perform the above functions the radio-frequency head is arranged according to the block diagram shown in figure 26.

The antenna switch consists of a main waveguide with a discharge tube for blocking the magnetron (RBP) and one wide-band discharge tube for protecting the receiver (RZP).

When transmitting, a high-power pulse from the magnetron causes the discharge tubes to disrupt and fire and an infinitely large resistance is created at the input to the receiver channel (according to the rule of quarter-wave sections of long lines); in this case all the energy of the magnetron passes to the antenna without significant losses, and the receiver mixer is blocked to the degree that the leakage power to the receiver channel cannot cause damage to the crystal detector.

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During reception of the reflected signal from the target, the magnetron channel is blocked by the transmitter blocking discharge tube, and since the tube is located at a distance which is a multiple of half a wavelength in the waveguide from the receiver protection discharge tube, an infinitely large resistance is formed at the input of the magnetron channel which prevents weak-signal losses in the magnetron branch.

Thus, the received signal enters the mixer of the receiver without significant losses. At the same time, the mixer receives high-frequency oscillations from the klystron oscillator which operates continuously at a frequency differing from the received signal by the value of the intermediate frequency.

Due to the nonlinear characteristic of the crystal detector, an i-f signal voltage appears at its output and passes to the i-f amplifier.

Simultaneously, the firing voltage is applied to the trigger electrode.

There is a separate channel for the AFC system which is connected
SPN 70 to the magnetron channel through a cutoff attenuator. The purpose of the attenuator is to weaken the power diverted to the magnetron channel to the level required for normal operation of the AFC mixer.

Operation of the AFC mixer is identical to that of the receiver mixer.

The difference frequency signal taken from the output of the AFC mixer enters the input of a special circuit, and from the output of this circuit a control voltage moves to the reflex klystron. Hence, the frequency of the klystron oscillator is regulated by the AFC circuit by changing the voltage applied to the klystron until the difference between the frequencies of the klystron and the magnetron equal the intermediate frequency.

In this manner, up until the moment of arrival of the signal reflected from the target, the frequency of the klystron oscillator is adjusted to the frequency of the received signal.

v) The magnetron oscillator

The range-only radar "Kvant" uses a type MI-158 multicavity magnetron to generate high-frequency oscillations.

At the present time multicavity magnetron oscillators are the basic type of radar oscillators for the centimeter-wave band. This can be explained by the fact that multicavity magnetrons have a number of advantages over other types of high-frequency oscillators. For in-
SPN 71 stance, multicavity magnetrons are capable of providing large values of power in a pulse of comparatively small average power, and they have a high efficiency which may reach 70%.

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The magnetron oscillator operates in a pulse mode with a pulse repetition rate of 800 cps and generates high-frequency pulses having a pulse power $P \geqslant 5$ kw. Frequency of the high-frequency oscillations is 9,370 ± 45 Mc.

The principle of operation of the magnetron may be represented by a diode in which the flow of electrons is acted upon not only by an electrical field, applied between the anode and cathode, but also a magnetic field which is created with the aid of permanent magnets and directed perpendicular to the electrical field.

As a result of the action of the electrical and magnetic fields on the flow of electrons, the trajectories of the electrons are distorted. Their movement may be represented by the curves shown in figure 27.

This curved electron flow, in passing close to slots which connect the cavity resonators with the cavity between the anode and cathode, releases its energy and excites high-frequency oscillations in the cavity resonators which, by means of coupling loops, are fed to the main waveguide.

The cavity resonators and the slots form the oscillatory system of the multicavity magnetron; the shape of one resonator with a slot is shown in figure 28.

Thus, the cylindrical portion may be considered an inductance L,
SPN 72 and the flat portion -- the capacitance of an oscillatory circuit whose natural frequency f_o may be approximately determined from the formula:

$$f = \frac{1}{2\pi\sqrt{LC}}$$

In view of the presence of many resonators in the magnetron, its oscillatory system proves to be very complex and, as is known, has not one but several resonance frequencies. In order that oscillations of only one frequency be excited in the system and that the frequency of the oscillations be stable, so-called cavity resonator strips are used.

The cavity resonators are arranged in a circle in a heavy copper block. A coupling loop is inserted into one of the resonators to conduct the high-frequency energy to the main waveguide, which transmits it to the antenna. One end of this loop is soldered to the wall of the resonator and the other end is placed within the waveguide. An inner wire of the line passes through a glass seal which serves to hermetically seal the inner space of the magnetron.

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In the middle of the anode block is a cylindrical heater cathode, which has a comparatively large diameter, providing a sufficiently large active surface necessary to obtain a large emission current. On both sides of the cathode are shielding discs which improve the structure of the field in the interaction space.

SPN 74 The cathode is fastened within the magnetron by means of holders which serve simultaneously as the cathode and filament leads.

A node on the holder performs the function of a high-frequency choke and prevents the flow of high-frequency energy through the filament leads.

A permanent magnetic field is created with the aid of a magnetic system consisting of a horseshoe magnet.

When a negative pulse equal to 5,500 v flows to the cathode of the magnetron, the magnetron is excited and generates high-frequency oscillations which, with the aid of the coupling loops, are fed to the waveguide.

For convenience and safety of operation, the anode of the magnetron is grounded (since it is not convenient to insulate the anode because of the large dimensions involved), and a modulating pulse of negative polarity is applied to the cathode.

g) Schematic diagram of radio-frequency head

A schematic diagram of the radio-frequency head is given in figure 29.

The radio-frequency head consists of three basic parts: the antenna switch, the oscillator (heterodyne), and the mixer device.

We will examine each of these parts.

Antenna Switch

SPN 75

The antenna switch, as was noted above, consists of discharge tubes for blocking the transmitter (RBP) and for protecting the receiver (RZP).

Discharge tube type RR-50 is used as the RBP and wide-band discharge tube RR-21 is used as the RZP. Both types are designed to

operate in the required frequency range.

For purposes of improving matching, a part of the main waveguide in the plane of RZP is made in the form of a 120-degree degenerate Y-joint. To accelerate the discharge, the RZP is equipped with a special firing electrode which is supplied by a current-stabilized firing rectifier.

SPN 77 When operating the antenna switch under low-temperature conditions, special attention should be devoted to one other parameter of the discharge tubes -- the recovery time. It is known that recovery time increases sharply with a decrease in ambient temperature. This means that the sensitivity of the radar set at negative temperatures will be considerably less than required during the recovery period of the discharge tube, which corresponds to a range of 1,000 to 2,000 m. Therefore, a warming system is used in the antenna switch to achieve a normal recovery time.

The warming system comprises a heating element and a thermoregulator.

A schematic diagram of the system is given in figure 29.

The heating element and thermoregulator are placed in discharge tube RR-21. The magnetron blocking discharge tubes do not have special heaters since they have less effect on the total recovery time of the antenna switch.

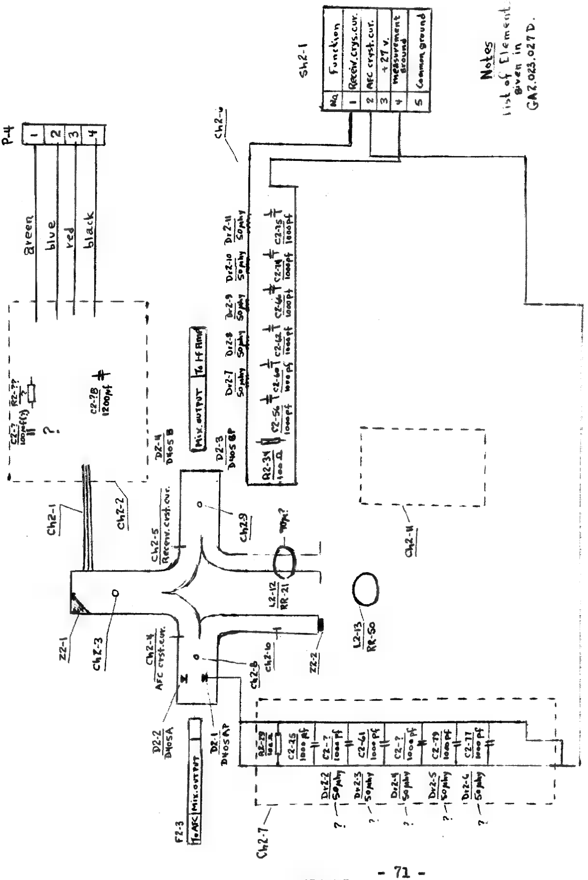
Let us examine the heating system for RZP.

Under normal temperature conditions when the set is switched on, contacts 2 of the thermoregulator are open and the heater is switched off.

The thermoregulator has been adjusted so that contacts 2 close at a temperature of no less than + 5°C, and open at a temperature greater than + 40°C. The heater for the discharge tube are switched on in this manner through contacts 2.

SPN 78 As soon as heating begins, the temperature in the shell of the discharge tube begins to rise.

Thus, the heater system will automatically maintain the temperature in the shell of the discharge tube within limits up to + 40°C with ambient temperatures up to - 60°C. A bimetallic strip relay is used for the thermoregulator.



Key to figure 29.

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Mixer Device

The mixing device is designed as a balancing network. High-reliability silicon detectors type D405-B, D405-BP are used as mixers in the receiver channel, and type D405-A, D405-AP in the AFC channel.

The use of a balancing network makes it possible to suppress klystron noises at the output of the mixer; thus, there is a gain in sensitivity on the order of 2 db. The balancing part of the mixer is a slotted bridge. The bridge connections are compact and wideband.

The slotted bridge is formed by two sections of a rectangular waveguide with a common with a common narrow wall. In this common wall is a slot which forms a coupling section between the two waveguides (fig. 30).

The properties of the slotted bridge are completely identical for any arm under conditions when the remaining three arms are loaded with matched loads.

If a power is applied to arm "1", it will be divided in half between arms "3" and "4" and will not go through arm "2".

SPN 79 This property of the bridge is explained by the fact that two types of waves originate at the boundary of the coupling section which compensate for each other in arm "2".

An important property of the bridge is that the wave in arm "4" leads the wave in arm "3" by 90 . Thus, the power levels in both arms are identical. With a phase shift differing from 90 , the division of power in the arms is unequal.

In the practical design of the slotted bridge, equal power distribution at the average frequency of the waveband is achieved by tuning the slotted bridge with a capacitance control screw.

When the slotted bridge is used in the balancing mixer, crystal mixers are attached to arms "3" and "4". A mixer circuit with reversed polarity of the crystals is used in the described radio-frequency head (see fig. 31). This drawing shows only the high- and intermediate-frequency circuits.

Let us examine how klystron noise suppression occurs in this case. The physical nature of i-f noises of the klystron are the same as for the received i-f signal. At the same time, the noise components of

the noise spectrum of the klystron, the frequency of which differs from the carrier frequency by the value of the intermediate frequency, are mixed with the carrier in the mixer and produce klystron noise, which have been converted to i-f, at the output of the mixer. The amplitude of these noises is proportional to the power of the klystron. From here their further amplification in the i-f amplifier is undesirable, since they increase the total noise of the receiver and decrease sensitivity.

SPN 81

Mathematical analysis shows that if the signal were directed into the same arm as the oscillations of the local oscillator, there would appear at the output of the mixer with reversed polarity crystals i-f voltages which would be equal in amplitude but opposite in phase.

If the signal were directed into one arm and oscillations into an adjacent arm (see fig. 31), the i-f voltages at the output would be equal in amplitude and in phase.

Following this explanation it is clear that the oscillator noises entering the same arm as the carrier are cancelled at the output, while the i-f voltages of the signal are added, since the oscillations of the signal and the oscillator enter different arms of the slotted bridge.

Figure 32 shows that in the d-c component circuit both crystals are connected in series and the same current passes through the crystals. Therefore, it is possible to control the current of any one crystal. This control is carried out by measuring the voltage drop across a known measuring resistor (in our case, 100 ohms.)

Series connection of the crystals in the d-c component circuit provides for automatic positive field current in one crystal from the current of the other. Such a mixing circuit has a balancing action. No matter to what extent the crystals differ in d-c resistance, impedance at high frequencies, and in other parameters, when they are connected in such a circuit the current in the crystals becomes completely identical and the parameters of the crystals approach each other.

SPN 82

This latter condition is very necessary from the viewpoint of the degree of suppression of klystron noises.

As seen from the circuit (fig. 29), the balancing mixer has a single-cycle output and is connected to the input of PUPCh (i-f amplifier) by a single high-frequency cable.

From the viewpoint of coupling to the input of the i-f amplifier and measuring crystal currents, a balancing mixer with reversed crys-

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tal polarity in no way differs from a single-cycle mixer.

In the AFC mixer channel (after the cutoff attenuator [7]) (see fig. 29) is a variable resistive attenuator [6] for adjusting the signal amplitude from the main waveguide to the necessary value. The cutoff attenuator is a circular opening in the waveguide. The attenuation of the cutoff attenuator depends on the diameter and length of the opening. An Alsifer probe is inserted into the opening of the attenuator to suppress high harmonics of the magnetron signal.

The variable attenuator is a pertinax plate covered with carbon. Maximum attenuation of the attenuator is not less than 25 db with a standing-wave ratio of no more than 1.4. Attenuation of the cutoff attenuator is equal to 51 ± 3 db.

SPN 83 Current in the AFC crystals is measured in the same manner as in the receiver crystal -- with the aid of a special filter box consisting of capacitors and inductances.

Oscillator

Klystron K-27 is used as the local oscillator in the r-f head of object RB6-2M.

R-f oscillations from the oscillator [14] enter the head through a special coaxial waveguide junction [15] (fig. 33) which is connected to one of the arms of the distributing slotted bridge. The energy of the oscillator is distributed in the slotted bridge between the AFC and the receiver channels. The fourth arm of the distributing slotted bridge is loaded with a matched absorption load made in the form of a wedge of special shape. The standing-wave ratio of the load is no greater than 1.2 [16].

The oscillator and antenna channels are bypassed through the use of the balancing circuit of the mixers, which eliminates the passage of energy from the oscillator to the antenna and the signal to the oscillator.

Regulation of the power of the klystron entering the mixer is accomplished by the use of variable attenuators [4,5] of the laminated, knife-type. Attenuation is introduced by lowering the plates into the waveguide. Attenuation is not less than 25 db with a standing-wave ratio not greater than 1.4. The absorbing plates improve the matching of the klystron load.

SPN 85

d) Design features of the radio-frequency head

A general view of the radio-frequency head is given in figure 34.

In order to decrease weight, the entire radio-frequency head is made with aluminum waveguides. The slotted bridges, attenuators, and the detector section are made of 10 X 23 mm waveguide sections.

For compactness, the entire receiver section of the radio-frequency head is designed in the form of a four-component subassembly. All four detector sections of the two balancing mixers are located in a line, and replacement of the crystal detectors may be carried out from one side of the radio-frequency head.

When replacing the crystals it is necessary to make sure that the type and polarity of the crystals correspond to the type and polarity specified in the r-f head. When this is not done, crystal current will be very small or close to zero and sensitivity will drop sharply.

The r-f head has two controls for regulating the crystal current of the receiver and AFC mixers. The controls have lock nuts.

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The local oscillator section is attached to the unit separately from the remaining part of the r-f head and is connected to the latter by means of a coaxial waveguide junction.

The radio-frequency head also has a filter box consisting of capacitors and inductances which are connected to the crystal current measuring circuit.

17. Automatic Frequency Control of the Klystron

AFC (Figure 42)

The frequency of the magnetron oscillator and the klystron oscillator may change during operation of the radar. This change may be caused by a change in ambient temperature, pressure, power supply voltages, or for other reasons.

At the same time a change will occur in the intermediate frequency, which is equal to:

$$f_{int.} = f_{kly.} - f_{mag.} ,$$

where: f int. is the intermediate frequency, f kly. is the frequency of the klystron oscillator, and f mag. is the frequency of the magnetron oscillator.

The AFC system is intended to maintain a constant intermediate frequency by electronically adjusting the frequency of the klystron oscillator to that of the magnetron oscillator. The AFC system operates from the natural pulse of the transmitter. For this purpose there is a branch in the main waveguide line through which part of the energy of the magnetron oscillator is diverted to the mixing chamber of the AFC. This branch of the waveguide line is a cutoff attenuator with an

SPN 88 attenuation on the order of 50 db.

This attenuation is determined by computing the maximum leakage power to the crystal which will provide for its normal operation.

The load of the crystal detector is the input circuit of the AFC circuit in which the difference frequency voltage is derived.

Operation of the AFC is of a "searching" nature.

The "searching" AFC is capable of tuning the klystron oscillator within wide limits.

The AFC circuit functions in the following manner:

At the moment of emission of a main pulse, a difference frequency pulse passes from the crystal mixer to the input circuit, which is tuned to a difference frequency of 30 Mc.

The first stage of L2-17, comprising tube 6Zh1B, is the i-f amplifier whose anode load is the standard band circuit TR2-8, which is tuned to a frequency of 30Mc.

The bias in the control grid is automatic and is formed by a drop in voltage across resistor R2-47. Capacitor C2-39 is blocking for the difference frequency. Capacitor C2-38 blocks the screen grid and is a filter for the + 150 v circuit.

The amplified difference frequency pulse passes to the control grid of tube L2-18, which is the second i-f amplifier stage. Amplification of this stage is controlled by changing the negative bias at

SPN 90 the control grid of the tube. A change in bias is made with the aid of potentiometer R6-5 ("AFC Gain") located on the control panel K-6.

In its normal state tube L2-18 is closed and opens only at the

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SPN 90 moment of emission of the main pulse, when a positive AFC trigger pulse (80 v) is applied to the screen grid.

Thus, the AFC system operates only on the basis of a natural signal, and will not respond to other signals.

From the anode load of tube L2-18 -- a resonance circuit comprising coil L2-20, the output capacitance of the tube, and the mounting capacitance, a signal passes to the discriminator, which is based on tube L2-19 (6Kh2P) (Fig. 35).

The discriminator is one of the basic elements of the AFC system: it converts the change in difference frequency to changes in amplitude of a video pulse, the value and sign of which vary according to changes of difference frequency relative to a frequency corresponding to the zero error signal of the discriminator or, as we will henceforth call it, the crossover frequency.

The input circuit of the discriminator (coil L2-21 and capacitor C2-46 and C2-47) determines its most important characteristics: the width of the frequency band (the frequency separation of the positive and negative humps of the frequency characteristic), and the crossover frequency.

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Resistor R2-59 and capacitor C2-49 make up the load of one diode of the L2-19 tube, while the resistor R2-60 and C2-50 make up the load of the second diode of L2-19.

These loads are connected symmetrically with respect to the discriminator, while the voltages on them are subtracted. Consequently the output voltage of the discriminator represents the difference of voltage taken off the load of each diode of the L2-19.

Shown in figure 36 are all stages of the transition from the schematic diagram of the input circuit to the equivalent circuit.

According to the diagram, capacitor Ca is equivalent to the capacitance introduced in the circuit by both diodes. Capacitors C2-46, C2-47, and C3 make up a triangle which is replaced by an equivalent star of capacitors Cl, C_1, C_{sh}.

Resistors R2-57, R2-58 make up the "middle point" of the coil L2-21, and are replaced by one resistor Ra, directly connected with the middle point of the coil L2-21.

Shown in figure 37 is the complete equivalent circuit of the discriminator. In the circuit, preceding the discriminator, the L2-18 tube amplifier is replaced by an equivalent generator "T."

Half of coil L2-21 and capacitors Cl and CII make up two resonant series circuits, tuned to frequencies f_1 = 28 and f_2 = 32 megacycles.

With a change in the value of the inductance of the coil L2-21, a certain retuning of circuits I and II is possible, and consequently, a change in certain range of frequencies for the

crossover of the discriminator response. Since the Q-factor of the circuits is different, amplitude asymmetry of the negative and positive humps of the frequency characteristics results.

Since in the circuit under examination only the positive hump of the frequency characteristic of the discriminator is used, the amplitude asymmetry of the humps is quite permissible and is even desirable.

As a result of applying a frequency difference pulse on its input, a video pulse ["signal-error"] is generated at the output of the discriminator. The magnitude and sign of the error signal depend entirely on the extent of deviation at a given instant, of the difference of heterodyne and magnetron frequencies from the intermediate frequency. The characteristic of the discriminator is shown in figure 38.

If the difference frequency is less than the crossover frequency, the error signal is positive and is all the higher in amplitude the greater the difference frequency differs from the crossover frequency, and vice versa, if the difference frequency is greater than the crossover frequency, then the error signal is negative and is all the higher in amplitude the greater the difference frequency differs from the crossover frequency. From the output of the discriminator the error signal passes through capacitor C2-51 to the control grid of the video amplifier tube L2-20-a [6N3P] and from the plate load of this amplifier R2-62 to the second stage of the video amplifier [L2-20-b].

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From the plate of L2-20b the video signal passes through capacitor C2-56 to the control grid of the regulator tube L2-21b [6N2P], which operates as a grid-leak detector. p 96

We examine the operation of the grid-leak detector shown in figure 39.

If on the last video amplifier a positive video pulse appears, then capacitor C2-56 starts to charge up with respect to the C2-56 circuit: the grid-cathode section of the tube L2-21b, C2-57a, ground, the 150-volt power supply, R2-66, R2-65, C2-56.

The time constant of this circuit is small, since during the time of duration of the video pulse the capacitor is able to charge up almost to the amplitude value of this signal.

After termination of the video pulse, the capacitor starts to discharge through the circuit: internal resistance of the tube L2-20b, ground, capacitor C2-57a, resistor R2-75, capacitor C2-56.

The time constant of this circuit is large, and capacitor C-56 is not able to discharge completely before the arrival of the next pulse.

The discharge current causes the appearance on resistor R2-75 of ■ voltage, applied negatively with respect to the control grid, which drops the current through tube L2-21b.

Because of this, the voltage drop across resistor R2-73 is lowered, and the negative voltage at the output and feeding the klystron heterodyne repeller rises, which increases the generating frequency of the klystron.

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Therefore, the next pulse arriving in the APCh (AFC) system will have a higher difference frequency. In the discriminator, this pulse is converted to a video pulse with a smaller amplitude than the preceding video pulse. This is clear from the frequency characteristic of the discriminator (figure 38).

Since capacitor C2-56 is not able to discharge completely before the arrival of the next video signal, it is only given an additional charge from this signal, but of a smaller magnitude.

In the event of arrival of the pulse at the input, the difference frequency which equals 30 megacycles, in the grid detector is established balance, i.e., the capacitor is given an additional charge equal to the discharge prior to the arrival of the next video pulse. At the output of the AFC, in this case, the voltage, which is fed to the klystron repeller, is changed little and the klystron frequency remains, in fact, fixed.

If the difference frequency is changed in a manner such that it becomes larger than the crossover frequency, then the circuit of the AFC converts to the search mode. On the output of the discriminator and subsequently, on the output of the video amplifier, will appear negative pulses, which will not provide an additional charge to capacitor C2-56.

Consequently, the negative voltage on the grid of tube L2-21b will be lowered, which will lead to an increase in the plate current of tube L2-21b.

Moreover, the negative voltage on the cathode of the tube L2-21b will be reduced so rapidly and reach such a value that the blocking generator tube [L2-21a] opens.

The blocking generator [L2-21a] operates in a wait mode.

The oscillations of this generator, from the cathode of the tube L2-21a through capacitance C2-54 and resistor R2-59, are applied to the grid of the video amplifier [tube L2-20b].

Since there is a zero potential on the control grid of this tube, the positive pulses of the blocking generator are clipped because of the grid currents of the tube, while the negative pulses, which were previously differentiated, are amplified.

From resistor R2-65, which is the plate load of tube L2-20b, the amplified pulses of positive polarity are fed to the grid detector [tube L2-21b].

As a result of the detection of these positive pulses, capacitor C2-56 charges.

Moreover, the negative grid bias of L2-21b increases, which leads to a drop in the current of this tube and an increase in the negative voltage at the cathode.

This increase in negative voltage reaches a value such that the blocking generator tube is cut off.

After this, capacitor C2-57 begins to discharge slowly until the blocking generator does not open again.

This "search mode" will be continued until the difference frequency remains equal to 30 megacycles. Now, the APCh (AFC) circuit is automatically returned to a regulating mode, while the blocking generator at this moment is cut-off.

A potentiometer R2-71 serves to establish the necessary value of the reference voltage for the APCh search, with the aid of which the voltage on the cathode of the blocking generator is regulated. This voltage is established in a manner such that its value correspond

to the middle of the generating region of the klystron.

A general view of the APCh (AFC) is shown in figures 40 and 41

The schematic diagram is shown in figure 42.

18. Structural Design of the Unit [Figure 43]

The receiving-transmitting unit is structurally on a welded chassis, which is rigidly fastened by screws from the front panel. The chassis of the unit is housed in a cylindrical case on which a ring moves to fasten the case to the front panel of the unit. The maximum diameter of the unit D = 240 millimeters, the length L = 368 millimeters.

To provide the unit with the necessary air tightness from the internal side of the front panel, there is a circular groove containing a rubber lining.

The flange of the case is fastened to this lining by the movable ring using screws with washers and springs. There are fins on the case to increase the cooling surface.

On the front panel of the unit are located:

a) 17-pin sealed plug-type connector for connetion with the intermediate cable.

b) Sealed waveguide outlet for connecting the antenna-waveguide system to the receiving-transmitting unit.

v) Sealed high-frequency plug-type connector which serves to [SPN 101]
connect the PUPCh with the main UPCh.

g) Sealed high-frequency plug-type connetor for blanking pulse outlet.

d) Nipple for pumping air.

Perpendicular to the front panel is fastened the chassis which has openings of complex configuration through which pass the projecting sections of the radio frequency head, the magnetron, and the envelope of the thyratron.

Located on the chassis from the top are: intermediate frequency preamplifier in the form of a separate subpanel, APCh (AFC) subpanel, recharge choke, pulse transformer, K-27 klystron, switch for primary winding of high-voltage transformer, shaping line.

Located underneath the chassis are: radio frequency head, magnetron, high voltage transformer, filament transformers, fan motor.

The magnetron generator is located so that the magnets with the oscillatory system of the magnetron are located in the lower part of the unit and the leads of the magnetron filament and the cathode are located in the upper part of the unit.

V. Range-only Radar Receiver Unit

19. Function of Unit

The range-only radar receiver unit is designed for:

a) Amplifying intermediate frequency signals and converting them to video signals

b) Search, lock-on, and range tracking of the target in the operating range, and generating a voltage proportional to the range to the target for two operating modes.

v) Signalling the lock-on of the target

In the absence of signals reflected from the target, the unit is in the search mode. The search range is set by the "RS-SS" switch

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located in the pilot's cabin. With the appearance of a signal reflected from the target, the unit is switched to the tracking mode and generates a voltage which is proportional to the distance to the target. With the simultaneous appearance of several targets in the zone swept by the range-only radar, the system for determining distance will lock-on the closest one of them, and a voltage will be established on the output of the unit proportional to the distance to it.

20. BASIC TECHNICAL CHARACTERISTICS OF THE UNIT

a) Search limits

in "A" mode -- 200-3,200 meters

in "B" mode -- 800-7,500 meters [SPN 108]

b) Dependence of range voltage on distance to target:

in "A" mode -- $Ud\,[v] = 195 - \frac{D[m]}{20}$

in "B" mode -- $Ud\,[v] = 195 - \frac{D[m]}{50}$

c) Maximum statistical error of introducing range voltage:

in "A" mode -- no more than ± 15 meters in a distance range of 400-2,000 meters

in "B" mode -- no more than ± 100 meters in a distance range of 800-7,000 meters

v) Search frequency -- 1 cycle ± 0.2 cycle

d) Resolution -- 200 meters

e) Storage time -- 2-3 seconds

zh) Triggering lag time of relay RZ-3 -- 1-1.5 seconds

z) Dimensions of unit -- 300 x 152 x 180

i) Weight of unit -- 4.7 kilograms

21. Description of Unit Operation Based On Functional Diagram (figure 48)

a) Search Mode

The negative triggering pulse, taken off of the winding of the pulse transformer of the modulator [unit RB6-2M], arrives in unit RB6-3, and through diode L3 is fed to the plate of the multivibrator for triggering a "fast saw" [L3-13]. The multivibrator is triggered by this pulse and generates a positive square wave of at least 50 microseconds, triggering the "fast saw" generator. The "fast saw" generator [L3-14] generates a negative saw-toothed pulse which is sent to the comparator circuit. The frequency of the saw-toothed pulses of the "fast saw" has the repetition frequency of 800 cycles, the amplitude changes from 195 to 35 volts.

In addition to saw-toothed pulses at the input of the comparison cir- [p 109] cuit, a voltage arrives which is generated by the search circuit. This voltage also changes according to the saw-toothed law, but approximately 50,000 times slower than the voltage of the "fast saw" [frequency of 1 cycle]. This voltage is sometimes called "slow saw", and the circuit generating this voltage, the "slow saw" generator. The "slow saw" voltage varies in the range from 135 to 20 volts.

As a result of comparing the "fast saw" and "slow saw" voltages, a negative pulse is generated on the plate of the comparator diode [L3-15], the onset of which, as the "slow saw" voltage decays, lags more and more behind the triggering pulse of the transmitter. This pulse is amplified by L3-22a, differentiated, and again amplified by L3-16a. The pulse on the plate of L3-16a triggers the range pulse blocking generator L3-16b.

The blocking generator generates a pulse with 0.7-microsecond duration and an amplitude of 100 volts called the range pulse.

This pulse is fed to the time discriminator circuit on the screen grid of the coincidence tube [L3-18] and through a 0.4 microsecond delay line to the screen grid of L3-18. The pulse taken from the delay line is sometimes called the "second" range pulse.

As is clear from figure 7, in the search mode, as the "slow saw" voltage diminishes, the range pulses are shifted in the direction of an increase in the range. Therefore, with the operation of the "slow saw" generator, they pass periodically, once a second, through the entire distance range.

From the plate of the receiving channel [L3-7], the noise voltage arrives at the output of the circuit for automatic gain control of noise.

The circuit maintains a constant receiver noise level with a variation in external factors [power supply voltages, tube aging, etc.].

To eliminate the influence on the operation of the AGC noise circuit of reflected signals, the circuit is modulated by a negative pulse of about 50 microsecond duration, applied on the suppressor grid of L3-9.

The windings of relays R3-1, R3-2, and R3-3 in the search mode are de-energized, the relays are in the released state.

b) Tracking Mode

The pulses reflected from the target, preamplified in the receiving-transmitting unit, arrive at the input of the intermediate frequency amplifier [L3-1--L3-5]. Amplified in the UPCh (IF amp.) and detected by the second detector [L3-6a], the target signal arrives at the input of the video amplifier [L3-7a]. After amplification through the cathode follower L3-7b, the target pulse is fed to the input of the time discriminator [L3-18, L3-17].

No coincidence circuit and the recharging diodes with the capacitance integrator [sometimes called the diffference detector] make up the time discriminator. In the search process, the range pulses, passing through the entire range band, at a certain time coincide with the target pulse. Negative pulses appear on the plates of the coincidence tubes, feeding into recharging diodes and the automatic lock-on circuit. Relay R3-1, which is the primary actuator of the automatic lock-on circuit, operates and engages relays R3-2 and R3-3.

After operation of all relays, the unit converts from the search mode to the tracking mode. One of the relay contacts feeds a signal of -27 volts to the sight and the "lock-on" signal lamp in the sight goes on.

Starting from this instant of time, the position of the range pulses is not controlled by the "slow saw" voltage, but by the voltage produced by the control unit circuit and depending on the magnitude and sign of the error arriving at the input of the duplex integrator from the time discriminator circuit.

Relays R3-2 and R3-3 switch over the elements of the "slow saw" generator circuit [L3-23], and the latter becomes the second integrator of the control unit.

The voltage on the plate of the first integrator [L3-26], which until lock-on is determined by the "wait" voltage taken off of the grid of L3-26 from the divider R3-36 and R3-133, after relay operates will be determined by the magnitude and sign of the error current from the output of the time discriminator.

Upon lock-on on the target, the target pulse usually p 112 coincides with the second range pulse at first. Now, the time discriminator circuit produces the negative error current [in the direction from the first integrator and to the time discriminator].

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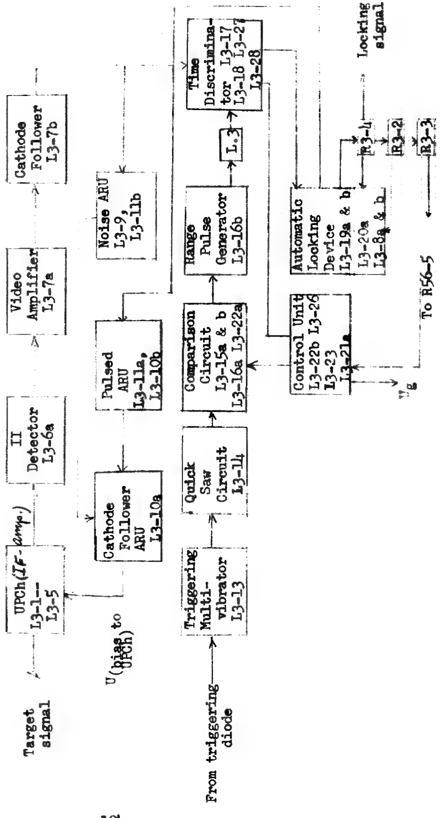

Key for Figure 48

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Tube L3-26 in this case cuts off and the voltage on its plate increases, which results in the opening of relay L3-23 and, subsequently, the reduction in plate voltage. This voltage controls the range pulses through the cathode follower L3-22b. The reduction in this voltage brings about the shift of range pulses toward a large range, that is, the range pulses coincide with the target. During the movement of the target, for example, on the approach, greater agreement takes place between the target and the first range pulse. Moreover, the sign of the error current becomes positive, tube L3-26 opens, and tube L3-23 cuts off. The voltage on the plate of L3-23 rises, which causes the range pulses to move toward the same side and at the same rate as the target pulse.

Range tracking is effected in this manner. The properties of the control unit circuit with two integrators make is possible to track a target moving at constant velocity without dynamic error, while the voltage on the plate of the first integrator (L3-26) is proportional to the velocity of the target.

The voltage controlling the movement of the range pulses and [SPN 113] taken off of the cathode follower L3-22b, during tracking is proportional to the distance to the target. This voltage goes through the cathode follower L3-21a and is fed: a) in mode "A" to the sight computer, b) in mode "B" to comparator unit K-8.

Relay R3-3 trips within 1-1.5 seconds and the lag of the servo mechanism of the range unit increases, as a result of which fluctuations in the reflected pulse do not affect the range voltage.

At the same time, relay R3-3 transmits a smoothing signal to unit RB6-5 which increases the lag of the servomechanism of the velocity unit.

To maintain a constant target signal level, there is a device for automatic pulse gain control in the range unit. The pulse arrives at the circuit input from the amplifier plate of the automatic lock-on [L3-19a].

This pulse is amplified, detected, and as a negative bias is fed to the control grid of the UPCh tube through the cathod follower L3-10.

It is essential that the reflected signal be maintained at a constant level to provide accuracy in determining the distance to the target.

The operation of the ARU noise circuit is identical in the search mode and in the tracking mode.

A detailed description of the operation of the elements in the ARU circuit is given in the section titled "Receiver".

22. Description of the Operation of Unit Based On Schematic Diagram (Figure 73) [p 116]

a) Trigger Multivibrator [Figure 49]

For normal operation of the "Fast Saw" generator it is necessary that the pulse have an amplitude of at least 25 volts and a duration of 50 micro-seconds. This pulse is generated by the multivibrator, which is assembled on the basis of a circuit with cathode coupling to tube L3-13 [6N3D].

In the initial state the right half of the tube is open, since there is a zero potential on the control grid and the

cathode, through R3-69, is connected with a -150-volt source. The current of the right half of the tube, flowing across the cathode resistance [R3-69], creates a voltage drop across the cathode closing the left half of the tube. The initial voltage from the divider R3-126 and R3-127 is applied on the grid of the left half of the tube. The magnitude of this voltage is chosen so that taking account of the bias in the cathode the left half of the tube will be reliably closed in the initial state, and the multivibrator will be triggered dependably upon application of the triggering pulse. The multivibrator is triggered through the cut-off diode L3-12b, which is necessary for clipping off the positive portion of the triggering pulse.

With the presence of a positive blip in the triggering pulse, the multivibrator becomes critical with respect to the magnitude of the triggering pulse and,consequently, undependable in operation.

The triggering pulse is fed through the diode to the plate [SPN 117]
of the left half of the tube and through the capacitor C3-47 to the control grid of the right half, thereby closing it.

The current in the right half is diminished, lowering the voltage drop across the cathode resistance of the multivibrator, and the voltage on the plate lode R3-68 is increased.

The lowering of the cathode bias opens the left half of the tube and results in a voltage drop on its plate. The voltage is transmitted through C3-47 to the grid of the right half, facilitating its blanking still more. As a result of the process

described, the multivibrator is opened "reversed", the left half of the tube is opened, and the right half is closed.

Capacitor C3-47, which in the initial state was charged to nearly the full voltage of the power supply, begins to discharge through the left half of the tube which is open. The capacitor discharges through the following circuits: internal resistance of the left half of L3-13, R3-69, internal resistance of power supply, R3-70. In flowing through R3-70, the discharge current creates a voltage drop across R3-70, which maintains the right half of the tube in the blanked state.

As the capacitor discharges, the discharge current gradually decreases, leading to a reduction in the voltage blanking the right half of the tube. At a certain instant of time this voltage becomes, in terms of absolute value, less than the tube [SFN 118] blanking voltage, and current appears in the right half of the tube. The appearance of current leads to the reduction in voltage on the plate of the right half of the tube, and consequently to the blanking of the left half. In turn, the blanking of the left half of the tube facilitates more effective opening of the right half, as a result of which the multivibrator "reverses" to the initial state in which it was found before the arrival of the triggering pulse. The time constant of the discharge circuit C3-47 was chosen so that the blanking time of the right half of the tube is 60 microseconds.

As a result of this, a positive square pulse is separated on the plate load of the right half of the tube with the indicated

length and an amplitude of 20-30 volts.

This pulse is fed to the circuit of the "Quick Saw" generator. To monitor the normal operation of the multivibrator, the cathode of L3-13 leads out to a control point designated as "‾|_|‾" and located on the front panel of the unit.

b) Fast Sawtooth Generator [Figure 50]

Used as the " fast Saw" generator in the unit is a linearly-dropping voltage generator with plate-grid capacitance. The " fast saw" generator is made up of a tube L3-14 [6Zh2P] and has two operating modes.

In the first mode, mode "A", the generator produces a negative pulse with a linear leading edge of 25-microsecond length; and in mode "B", of 60-microsecond length [figure 51].

The change in pulse length is effected by connecting additional [SPN 119] resistors to the circuit of the control grid of tube L3-14, which are located in unit K-6, R6-17, R6-18, R6-19.

In mode A, they are shorted-out by relay R6-3 [contacts 1-9].

In the initial state, the tube is blanked through the plate circuit because of the application on the suppressor grid of a blanking voltage of -25 to -30 volts. The screen grid circuit of the tube is open so that the total plate supply voltage [+200 volts] is applied to the control grid through R3-72 and R3-73. The potential of the control grid is equal to approximately +1 volt.

Capacitor C3-49 is charged to nearly the total voltage fixed by the slider of the "zero range" potentiometer so that the voltage drop across the grid-cathode section can be disregarded

 [redacted]

because [redacted]

With the transmission to the protective grid of a positive pulse from the triggering multivibrator, the tube is opened through the plate circuit and capacitor C3-49 starts to discharge in the following manner.

a) In mode "A", internal resistance of L3-14, internal resistance of power supply, R3-78, R3-79, and R6-11.

b) In mode "B", internal resistance of L3-14, internal resistance of power supply, R3-72, R3-73, R6-11, R6-17, R6-18, and R6-19. In the first instant the voltage on the plate of L3-14 starts to drop sharply. This reduction in voltage is transmitted through C3-49 to the control grid of the tube, increasing its internal resistance and lowering, consequently, the discharge current of the capacitor. Since in the initial stage the voltage on the control grid is equal to approximately to +1 volts and the tube is completely closed at -6 volts, the initial negative voltage jump on the plate and on the grid of L3-14 is approximately 4-5 volts. [SPN 1[illegible]]

After the initial jump the linear discharge of capacitor C3-49 begins. The discharge current flows through the discharge resistors indicated above and creates a voltage drop across them, controlling the internal resistance of the tube. It is permissable in the process of discharge that the discharge current start to diminish. It is evident, moreover, that the voltage drop across the discharge resistors diminishes and the tube L3-14 opens. The opening of the tube lowers the resistance in the discharge

[redacted] [redacted]

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circuit and consequently increases the discharge current, returning it to the initial value. An increase in discharge currents cause blanking of the tube which also results in the establishment of the initial current value. Because of the presence of such control over the internal resistance of the tube, the discharge process, while the discharge of the capacitor at constant rate results, as is known, in a linear reduction in voltage on its plates.

Actually, the voltage on the capacitor plates during discharge can be expressed by the relationship: $U_c = U_{c0} - \frac{1}{C}\int_0^t i(t)\,dt$ (1) [p 123]

Sine to obtain a proportional relationship between the range voltage and the distance to the target it is essential to have a linear reduction in voltage, it is evident that the second term of the right side of the equality must be a linear function of time, that is: $\frac{1}{C}\int_0^t i(t)\,dt = Kt$

Solving this equation, we obtain: $i(t) =$ constant, that it is the necessary linear drop in voltage will be obtained during the discharge of the capacitor at constant current. During the discharge of C3-49 the voltage on the plate of the tube is reduced approximately to 20-25 volts, so that with an additional reduction in plate voltage the tube ceases to control the discharge current. The length of the saw-toothed pulse on the plate of L3-14 for the values of the circuit element used by us is 25 microseconds in mode "A" and 60 microseconds in mode "B".

Upon termination of the positive pulse on the protective grid, the tube again closes through the plate circuit. Capacitor C3-49 discharges through R3-74 and the grid-cathode section of L3-14, and the entire circuit returns to the initial state. The initial voltage on the plate of L3-14 is regulated with the "zero-range" potentiometer R6-15 located in the unit K-6. The steepness of the saw-toothed pulse is [p 124] regular by changing the time constant of the discharge circuit C3-49. Added to resistors R3-72 and R3-73 are the following:

a) In mode "A", a variable resistor R6-11 ["scale of range A"]

b) In mode "B", resistors R6-18 and R6-19, and potentiometer R6-17 [scale of range "B"], which are housed for convenience of regulation in unit K-6 also.

Since the voltage on the plate can be expressed by the relationship: $U_0 = E_a - \frac{E_g \cdot t}{RC}$ (2) where E_a is the voltage on the plate of L3-14 before arrival of the triggering pulse; E_g is the voltage supplied across the resistor in the control grid circuit [200 volts], t is time, R is the discharge resistance, C is C3-49, it is clear that regulation of the "zero range", effected by a change in E_a does not have any effect on the steepness of the pulses, which is regulated by the change in the value of the discharge resistor ["range scale"], and in turn does not affect the "zero range".

Thus is provided independent regulation of "zero" and "scale" [p 125] which is extremely convenient for operation [figure 51].

Resistor R3-76 in the screen grid circuit is designed to limit the current on the second screen grid during periods of

inactivity, that is when the tube is blanked through the plate circuit.

As evident from formula (2), the elements which determine the steepness of the "saw" in mode "A" are C3-49, R3-72, R3-73, and R6-11, and in mode "B", R3-72, R3-73, R6-17, R6-18, R6-19, and R6-11. To maintain a constant steepness with changes inthe surrounding temperature these elements are thermally compensated: R3-73 and R3-72 are made from manganin which has a low positive temperature coefficient, while for C3-49 type KTK-3"M" with a small negative temperature coefficient was selected. As a result, the quantity RC, which has an affect on the steepness, remains constant with a change in temperature, which is essential for providing a minimal number of errors in mode "A".

Diode L3-25b is designed to reduce the length of the flyback of the "saw" and to reduce the influence of leakage which is harmful under conditions of interaction of humidity on the accuracy of computing the range. Because of the diode, the steepness of the flyback "saw" voltage, as can be seen in figure 52, increases due to the increase in voltage Ea, which leads to a reduction in flyback time.

The effect of leakage can be represented by an equivalent resistor Ry connected between the plate of L3-14 and the frame. In the absence of a diode, the leakage results in a change in voltage on the plate by a quantity: $\frac{E_a R_y}{R_a+R_y}$ where Ra is the plate load of L3-14, Ry is the equivalent leakage resistance. SPN [illegible]261

This may cause an inadmissable error with respect to range.

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The presence of a diode results in a reduction of this error to a value which can be disregarded even for substantial leakage.

v) The Slow Sawtooth Generator [Figure 53]

The "slow saw" generator [search circuit] is designed to generate in the target search mode a slowly decaying saw-toothed voltage with a frequency of about 1 cps. The function of the "slow saw" generator is performed by the tube L3-23 [6N2P] and L3-22b [6N3P], which in the search mode act as a transitron generator of relaxation oscillations [in the tracking mode these tubes function as the second integrator].

For convenience of examination, we assume initially that the blanked state of the tube L3-23 in the plate circuit. Moreover, there is a voltage on the plate which is determined by the divider R3-124, R3-125. Since the control grid is connected to ground through R3-104, the tube opens and the plate voltage begins to decrease. This reduction in voltage is transmitted to the control grid through the cathode follower L3-22b and capacitors C3-59, C3-71 and, by increasing the negative bias, it prevents a rapid drop in voltage on the plate. The process occurring in the circuit is quite similar to the operation of the "fast saw" circuit, only in this case the discharge of the capacitors [C3-59, C3-71] occurs through the equivalent resistance of the output of the cathode follower circuit. [p 128]

Thus, in the process of discharge of C3-59, C3-71 a small negative voltage is maintained on the control grid. When the plate voltage reaches a value of 20-25 volts, as in the "fast

saw" circuit, the tube L3-23 ceases to control the discharge and the drop in voltage on the plate is retarded. Consequently, the negative bias on the control grid of L3-23 is reduced. The reduction in voltage on the control grid causes an increase in the current on the screen grid. The screen grid current, flowing through resistor R3-107, increases the voltage drop across this resistor and the screen grid potential drops.

The reduction in potential is transmitted through C3-73 to the suppressor grid of L3-23 and reduces the plate current of the tube. The reduction in plate current causes a rise in potential on the plate, and because of the coupling through L3-22b C3-59, C3-71, an increase in potential on the control grid. This causes an additional increase in screen grid current and the complete blanking of the tube through the suppressor grid.

The plate voltage rises rapidly and the process begins again. Connection of capacitors C3-59 and C3-71 directly between the plate and grid of L3-23 and through the cathode follower made it possible to lower the charging time significantly. If in the "quick saw" circuit this time is considerably greater than the discharge time, then in the given case the situation is reversed. The capacitors are charged through the small internal resistance of L3-22b and the plate voltage of L3-29 increases, in practice, gradually.

This is essential to provide quick fly-back of range pulses after which, in the search process, they achieve a maximum range. The quick fly-back guarantees locking on the target only with the movement of the range pulses in the direction of lengthening, that is locking on a close target. The presence of the divider in the plate circuit of L3-23 is specified by the necessity for limiting the start of the search for the preliminary locking on a main leakage pulse. The filter C3-74, R3-106 facilitates stabler operation of the "slow saw" generator.

The relaxation frequency is determined by the values of C3-59, C3-71, and R3-104 and is equal to one cycle. This corresponds to a search rate of approximately 10,000 kilometers per hour.

g) Comparator Circuit [Figure 54]

The comparator circuit dtermines the instant of equality of the values of the "fast saw" and "slow saw" voltages, and as a result, provides for the delay-triggering of the range pulse generator. The delay time is

determined with respect to the main pulse. The circuit consists of a comparator diode, a compensation diode, and a two-storage pulse generator. Used as the comparator diode is the left half of L3-15 [Fig. 55].

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The "fast saw" voltage is applied to the cathode while the "slow saw" voltage [in the search model] or the range voltage [in the tracking mode] is applied to the plate through the R3-77.

Since the voltage on the cathode is greater than on the plate, the tube closes and there is no signal at the output. However, as soon as the "fast saw" voltage becomes less than the "slow saw" voltage taken from the output of the duplex integrator, the diode opens and a negative pulse appears on its plate.

The start of this pulse, which is determined by the equality of the "saws", shifts in the direction of a larger delay with respect to the main pulse as the "fast saw" voltage reduces. From the plate of the comparator diode, the pulse is fed through C3-51 to the grid of L3-22a, the pulse amplifier. A positive pulse with an amplitude of more than 100 volts is generated on the plate of L3-22a [6N3P]. Because of amplification, the steepness of the leading edge of this pulse is considerably greater than on the grid, and the pulse is almost square. From the plate of L3-22a, the pulse goes to the control grid of the second pulse amplifier L3-16a [6N3P], through the differentiating circuit C3-53 and R3-79, which is essential for reducing the length. The second stage increases the steepness of the leading edge of of the pulse even more. This pulse, taken from the

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plate of L3-16a, goes to the control grid of L3-16b through a pulse transformer Tr3-7 and triggers the range pulse blocking generator. Because of the large steepness of the leading edge of the triggering pulse, the instant of triggering of the blocking generator does not depend heavily on the fluctuation of the feeding voltages, changes in tube characteristics, etc. This facilitates a reduction in errors in determining the range.

Since the instant of opening of the comparator diode determines the range-pulse delay, for precise operation of the entire unit, it is essential that it, as far as possible, also will not depend on the supply voltages, tube characteristics, etc. The volt-ampere characteristic of the diode is shown in Fig 55. It is known that under the influence of changes in the filament voltage and the diode aging, this characteristic "drifts", that is, it is shifted [for example, to the position shown in the figure by the dotted line]. Moreover, as can be seen from the construction, an error occurs in the instant of comparison Δt_0. This error enters directly into the over-all error of measuring the range. To reduce the influence of external factors on the instant of comparison a compensating diode is employed. For small negative voltages between the plate and the cathode a current appears between them. Therefore, even with the comparator diode closed, there will be a voltage drop across resistor R3-77 determined by the current of the compensating diode. This voltage is directed toward the

"slow saw" and the instant of opening of the comparator diode occurs somewhat later [t'_1 rather than t_1]. Now for the shift in the volt-ampere characteristic, the instant of comparison shifts to a point $t'2$, and the difference in time between t_1 and $t'2$, designated Δt_1, is considerably less than $\Delta t'_0$. Thus, the use of the compensating diode stabilizes the instant of comparison. In view of the large gain of the comparator circuit, even small influence of the triggering pulse can result in the triggering of the blocking generator at the point of zero range. In order to avoid this, a small negative pulse is applied through C3-77 to the grid of L3-16a blanking the tube at the initial instant of time. This pulse is obtained via the differentiating circuit C3-77, R3-79 of the triggering pulse. 135-6

d) Range pulse generator [Fig 56]

The range pulse generator is an ordinary blocking generator composed of the right half of L3-16 [6N3P].

In the initial state, the tube is blanked by a voltage of -14 volts taken from the common divider of the unit and fed through R3-81 to the control grid. At the instant of arrival of the triggering pulse, the tube opens and a current appears in the plate circuit. The appearance of the current results in a lowering of voltage on the plate of the tube. The windings of the pulse transformer are connected so that a reduction in potential on the plate results in an increase in potential on the control grid. The existence of such a circuit with positive feedback means that the plate

current increases still more, the grid voltage rises additionally, etc., to an instant when the tube current reaches saturation. This process of "reversing" the tube occurs very rapidly and is called the "blocking" process. The time for complete opening of the tube is usually about 0.1 microsecond. As a result of the termination of the direct blocking process the plate voltage drops to almost zero due to the voltage drop across the primary winding of the pulse transformer, while the grid voltage rises strongly and becomes positive because of the induced emf.

From the instant of time when the voltage on the grid becomes positive, a screen grid current starts to flow and capacitor C3-55 begins to charge.

At the end of the direct blocking process, the operating point on the tube characteristics shifts to the region of shallow steepness, that is, the change in voltage on the screen grid has almost no effect on the value of the plate current. As C3-55 charges the voltage on the control grid of the tube begins to diminish. However, since the operating point is located on the right portion of the characteristic, the plate current remains nearly unchanged for a certain time. The flat portion of the pulse is formed during this time. With time, the voltage on the control grid shifts the operating point of the characteristic to the region of great steepness.

The plate current is diminished more effectively, which results in a rise in the plate potential and, consequently, a reduction of voltage

on the control grid. The latter reduces the plate current still more and the inverse blocking process takes place.

The tube is blanked and the voltage across capacitor C3-55 attains a large negative value. After completion of the blocking process, this capacitor discharges through R3-81 and the circuit returns to the initial state.

The positive range pulse with an amplitude on the order of 100 volts and a duration of 0.7 microsecond is taken from the winding of the pulse transformer, fed to the screen grid of the tube L3-18 and through a 0.4 microsecond delay line to the screen grid of L3-17.

Capacitor C3-52 and resistor R3-78, connected to the plate circuit of the blocking generator, make up the decoupling filter which reduces the influence of the generator on the remaining elements of the circuit of the unit through the power supply circuit.

e) Time discriminator (Fig 57)

The time discriminator circuit consists of a coincidence circuit, with 6Zh5P tubes [L3-17, L3-18], and a difference detector circuit [recharging diode] with integrating capacitance consisting of 6D 6A tubes [L3-27, L3-28].

The function of the time discriminator is to fix the instant of coincidence of the target pulse with the range pulses and to generate a signal indicating the presence of a shift with respect to time between the pulses mentioned. The circuit generates this signal as a direct current, which is called the error current, of varying magnitude and sign depending upon the magnitude and direction of the mismatch between the range and target pulses.

In the absence of target pulses, the coincidence tubes L3-17 and L3-18 are blanked through the plate circuit by the presence on the control grids of a voltage of about -3 volts and on the screen grids of a voltage of -23 volts.

Besides, the range pulses arive on the screen grids of the tube. The pulse goes directly to the screen grid of L3-18, and through a 0.4 microsecond delay line to the screen grid of L3-17. These pulses shift periodically with time seeking out the target. If a pulse reflected from the target occurs on the control grids, then the pulses on the screen grids which are moving with respect to the range, coincide with them at a certain instant with respect to time. The tubes open and negative pulses appear on the plates. These pulses go to the difference detector circuit [L3-27, L3-28], and depending upon the relationship of their amplitudes, they are converted to an error current for the given direction. Taken from the resistor R3-35 and R3-[illegible] **connected between the plates of L3-17 and L3-18, is a negative pulse which is fed through capacitor C3-57 to the control grid of the automatic lock-on amplifier.**

Resistors R3-82 and capacitor C3-56 form a decoupling network which protects the plates of the coincidence tubes from the influence of power network. The coincidence tubes serve as the input of the automatic lock-on amplifier.

Let us assume that after lock-on the mutual position of the target pulse and the range pulses is as shown on fig. 58.

In this manner both coincidence tubes open, but because there is greater coincidence of the target with the second range pulse, the pulse in the plate of L3-17 has a greater amplitude and duration than the pulse in the anode of L3-18.

Furthermore, let us agree to regard the input of the double integrating circuit as a certain equivalent capacitance C_1. In considering the operation of this element of the range unit, let us satisfy ourselves as to the accuracy of such an assumption.

Capacitors C3-58 and C3-62, which are charged until coincidence to a value approximately that of the voltage of the power source, begin to discharge. Capacitor C3-58 discharges through the circuit: the internal resistance of L3-17, C_1, the internal resistance of L3-28. Up to coincidence, diode L3-28

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was closed by a voltage of +7v applied to the tube cathode. At coincidence, the diode opens, since a negative pulse with an amplitude up to 50v is applied to the cathode and thus the C3-58 discharge circuit is created.

The discharge current of C3-58 flows through a capacitance [143]
Ci, and it is seen by the direction of the current that the voltage at Ci must be decreased thereby, capacitance Ci discharges (the direction of the current is shown by the unbroken arrow).

Capacitor C3-62 discharges along the circuit: internal resistance of L3-18, resistance of negative voltage divider, internal resistance of L3-27. Diode L3-27 also was closed by a voltage of -14v and is opened by the coincidence pulse.

The discharge current of C3-62 does not flow through Si and evidently does not affect the potential at this point.

During the time between pulses, capacitors C3-56 and C3-62 are charged. The charge of capacitor C3-58 passes through R3-82, R3-83, R3-118, R3-129. The charging current of C3-62 passes through the integrator capacitance in the direction shown on the figure by the dotted line.

It is evident that the potential at C_i will increase under the action of this current.

In the case we have considered, the discharge of capacitor C3-58 has a greater effect than the charge of C3-62, since there

is greater coincidence with the second range pulse. Thus, voltage at the capacitor will be decreased from pulse to pulse, the total current will be directed from C i to a difference detector.

This current is also called the error current. This direction of current is called negative. The appearance of the current acts through the control unit (double integrator) on the range pulses, and they are displaced in the direction of greater range. Thus, a mutual position of the range pulses and the target pulse as shown in Fig. 58 and Fig. 59 is possible.

In the given case, greater coincidence occurs in L3-18, and the effect of capacitor C3-62 is increased. Discharging intensely at the moment of coincidence, capacitor C3-62 is charged by a current the value of which now exceeds the discharge current of C3-58, and the direction of the recharge current of of the integrator capacitance is changed.

Now the current is directed from the difference detector to the integrator capacitance, and the potential of the integrator capacitance increases. Let us call such a direction of the error current positive.

If the axes of symmetry of the range pulses coincide with the midline of the target (Fig. 60), the effect of C3-58 and C3-62 is equalized, and the potential at C i remains unchanged. It is evident that in this case the error current will be zero.

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Thus, the sign of the error current is changed depending on the direction of displacement of the range pulses relative to the target pulse. The dependence of the value of the error current on displacement is represented in Fig. 61.

The error current lies on the ordinate, and the displacement of the range pulses relative to the target in time, on the abcissa. The left branch of the characteristic corresponds to a lead of range pulses over the target pulse. The right branch corresponds to the delay of the range pulses.

Zh) Control Unit

(Double Integrator)

The purpose of the control unit (Fig. 62) is transformation of the error current, which flows from the output of the time discriminator, to a voltage which controls the range pulse delay. The circuit consists of two integrators--tubes L3-26 (6Zh1B), L3-23 (6Zh2P), and L3-22b (6N3P).

In mode "A," the range voltage is applied through cathode follower L3-21a (6N3P) to a sight, and in mode "B," to K-8. The circuit diagram of the anode-grid integrator is shown in Fig. 63.

Analysis of such a circuit shows that the dependence of the voltage at the anode on the current in the grid circuit can be approximated in the form:

$$U_a = U_{ao} - \frac{1}{C_g}\int_0^t i\,dt \qquad /3/$$

If we consider the circuit of the fast sawtooth generator which is a special type of integrator (Fig. 61), it is evident that the voltage U_a is supplied to the input of differentiating circuit RC, at the output of which there is a voltage which drops at resistance R, i.e., $U_d - E_d$.

For such a circuit the following relationship holds true:

$$U_{vykh(out)} = \frac{dU_{vykh}}{dt} RC$$

In our case: [P 52]

$$U_{d(range)} - E_d = \frac{dU_a}{dt} RC$$

$$\frac{dU_a}{dt} = \frac{U_d - E_d}{RC} = - \frac{i}{C}$$

Integrating both parts of this equation, we obtain:

$$U_a = C_o - \frac{i}{C} \int_o^t i\,dt$$

i.e., the equation of the integrator.

In the case $E_d = \text{Const}$, and disregarding U_d, we have:

$$U_a = C_o - \frac{i}{C} \int_o^t i dt = \frac{E_d t}{RC}$$

where $t = 0$; $U_a = Co$, consequently,

$$U_a = U_{ao} = \frac{E_d t}{RC}$$ i. e., we obtain the

equation for the fast sawtooth generator.

The integrator equation makes it possible to determine all the properties of the circuit.

For further description, let us recall that:

1. $\int_o^t 0 \cdot dt = \text{Const}$; 2. $\int_o^t a \cdot dt = at$; 3. $\int_o^t at\,dt = \frac{at^2}{2}$ [P 54]

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It is seen from these general mathematical expressions that when the current in the grid circuit equals 0, the voltage at the tube anode does not change since both sides of the equation are constants. In the presence of a constant current in the grid circuit, the voltage at the anode drops linearly where i is positive, or increases linearly where i is negative.

It is easy to derive a physical explanation of the processes in the integrator circuit, considering the charge and discharge of the equivalent integrator capacitance Si (Fig. 65).

A positive current (in our case "error current") charges the integrator capacitance, the voltage across it increases, and the tube opens.

The appearance of an anode current leads to a decrease in anode voltage. A negative current discharges C_i, the potential at the control grid decreases, the tube is blocked, and the anode voltage increases.

The validity of replacing the resistance of the integrator input by the equivalent capacitance C_i is evident from the following.

If we consider the circuit in Fig. 65, we see that:

$$U_0 = U_{0a} - K\frac{1}{C_u}\int_0^t i\,dt$$

where k is the amplification factor of the tube.

Consequently, the circuit depicted is equivalent to the integrator circuit wherein

$$\frac{1}{C} = \frac{K}{C_u}, \quad \text{i. e.} \quad C_u = KC$$

Following the above-stated considerations, which pertain to integrators in general, let us examine the operation of the actual circuit of the double integrator used in the unit.

The circuit consists of two anode-grid integrators connected by stabilizing circuit [illegible].

Let us assume that on locking on the target, the mutual position of the range pulses and the target pulse is that depicted in Fig. 58, i. e., the range pulses lead the target pulse.

As was explained during examination of the operation of the time discriminator, a negative error current flows to the integrator input in this case. The presence of a negative current leads to blocking of tube L3-26 of the first integrator, and the potential in its anode increases. The voltage at divider R3-114, R3-115 increases correspondingly.

The voltage from the common point of these resistances through R3-116 and R3-[illegible] is applied to control grid L3-26 which is the second integrator. In this case the current will be positive.

The appearance of a positive current in the grid circuit of the second integrator leads to opening of L3-23 and to a decrease in the voltage at its anode. The error current which flows to the input of the first integrator during a brief period can be considered constant.

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Then the voltage at the anode of the first integrator will increase linearly (since $\int_0^t a\,dt = at$). The current in the grid circuit of the second integrator, proportional to the voltage at the L3-26 anode, also will increase linearly. The voltage at the L3-23 anode will decrease at an ever increasing rate, since

$$\int_0^t at\,dt = \frac{at^2}{2}$$

This voltage through cathode follower L3-22b flows to the comparitor circuit (L3-15) and makes the range pulses shift toward the receding side, also at an ever increasing rate. The range pulses, shifting in this direction, go through the matching positions and begin to lag the target pulse in time. As we see in Fig. 61, the error current changes its sign and becomes positive.

This leads to opening of the first integrator and a voltage decrease at divider R3-114, R3-115; and inasmuch as R3-115 is connected to the point of the divider with a potential of -30 v, the voltage at R3-116 acquires a negative value.

The current in the second integrator circuit changes its [P 159]
sign, and the voltage at its anode begins to increase.

The increase of this voltage leads to shifting of the range pulses in the direction of decreased range, i. e., again toward matching with the target pulse.

After several such oscillations, the system reaches a

state of equilibrium in which the range pulses match the target pulse. In the event that the target moves at a constant rate, the voltage at the anode of the second integrator changes linearly. This will transpire, evidently, when there is a constant current in the grid circuit of this integrator ($\int a\,dt = at$), and signifies a constant voltage in the anode of the first integrator (Fig. 63).

Changes in the rate of movement of the target pulse must correspond to changes of current in the grid circuit of L3-23, and consequently, the voltage in the anode of the first integrator. Thus, the voltage in the anode of the first integrator is proportional to the approach speed. This conclusion can be drawn mathematically.

It is seen from the circuit that the voltage at the anode of L3-26 will be:

$$U_a = U_{ao} + iR$$

where: U_{ao} is the voltage at the anode of L3-26 when $i = 0$.

i = the current in the circuit connecting the output of integrator I and the input of integrator II.

$$R = (R3\text{-}116 + R3\text{-}104)\ \frac{R3\text{-}114 + R3\text{-}115}{R3\text{-}115}$$

Since expression (3) is correct for integrator II, and the voltage in its anode is porportional to the range to the target, then, having differentiated, we obtain:

$$\frac{dU_d}{dt} = \frac{i}{C}; \quad \text{i.e.,} \quad i = C\,\frac{dU_d}{dt}$$

where: $C = C3\text{-}59 + C3\text{-}7$;

consequently:

$$U_a = U_{a_0} + \frac{dU_d}{dt} RC$$

where: $\frac{dU_d}{dt}$ is the rate of change in the range voltage, proportional to the approach speed.

With the parameters used in the circuit, the voltage at the anode of L3-26 upon locking-on a stationary target is approximately +80v. Finiteness of the amplification factor of L3-23 leads to the fact that this voltage depends in addition on the range from the target, although to a negligible extent. In tracking an apporaching target, this voltage has a smaller values. At an approach speed of 300 m/sec, it reaches +60 v.

But if the voltage at the anode of integrator I is constant at a constant approach speed, this means that the error current in this case is zero, since

$$\frac{d(\text{Const})}{dt} = 0$$

The foregoing case demonstrates that a control unit with two integrators provides for tracking a uniformly moving target without dynamic error, since the error current is zero only when there is precise coincidence of the range pulses and the target pulse. Besides, this, as a result of the zero error current, the circuit is capable of tracking fading signals.

When the target fades out, the coincidence tubes close and no current flows from the output of the time discriminator to the input of the control unit. Thus the same voltage remains

at the anode of the first integrator as during tracking of the target. Since this voltage corresponds to the speed of the target until it fades out, tracking will continue at the same speed in the absence of a target. Upon the appearance of the target, it is again visible in the zone of range pulses and normal operation is continued. Owing to the presence of leak resistance between the grid and the cathode of L3-26, upon disappearance of the error current the voltage at the anode usually alters slowly in one direction or another, which leads to errors in tracking a fading target. To diminish these changes, the capacitance of the first integrator is switched, and within 1 $\div$ 5 seconds after locking, becomes equal to $\approx$ 40,000 pf. At the moment of locking, it is necessary to have a small time constant of the first integrator. Therefore, up to and at the moment of locking, the anode grid capacitor with a capacitance of 0.01 μf is turned on.

A time lag ($\approx$ 1 sec) is necessary for readying capacitors C3-75, C3-86. During this time, they succeed in discharging to the voltage which corresponds to the speed of the locked target.

The high value of the capacitance of the first integrator facilitates a decrease in the effect of target fluctuations on range voltage as a result of smoothing introduced by it.

To decrease the effect of leakage on the operation of the circuit, tubes L3-26, L3-27, and L3-28 are placed in a hermetically

sealed area, and are a separate, complete unit ("integrator I").

For more favorable conditions of locking, the voltage at the anode of the first integrator in the scanning mode is correspondingly set to the most probable target speed ("expected voltage"). This setting is made by applying a corresponding voltage to the anode of the first integrator from divider R3-36 and R3-133.

To improve the operation of the double integrator in the mode of a fading target, it is necessary to select at the screen grid of the tube of the first integrator such a voltage that when no target is present the voltage at the anode of the first integrator will be practically unchanged. The setting of the P 163] required voltage at the screen grid is done with the aid of potentiometer R3-113.

Capacitor C3-76 is intended to speed up precise matching of the range pulses with the target. Together with R3-116 and R3-104, this capacitor forms a so-called "stabilizing network", which prevents the occurrence of a self-oscillating system, i. e., "oscillation" of range pulses around the target.

The range voltage is applied from the output of L3-22b to the grid of cathode follower L3-21a.

Upon locking, a voltage proportional to the range to the target is applied from L3-21a to the external circuits.

<u>z) Automatic Locking Device (Fig. 67)</u>

The circuit of the automatic locking device is intended for switching the unit from the scanning mode to the locking mode. The circuit consists of amplifier L3-19b, peak detector L3-19a, and electronic relay L3-20b.

Electromagnetic relay R3-1, type RMUG, in the anode of L3-20, turns on relay R3-2, in the anode of L3-8a, and relay R3-3, in the anode of L3-8b. The operating time of relay R3-2 and relay R3-3 depends on the bias at the grids of L3-8a and L3-8b, which is controlled by "delay" potentiometer R3-60.

The circuit of the contact groups of the automatic locking relay is shown in Fig. 68.

In the scanning mode, the entire relay is in a released state. Tube L3-20 is blocked by a negative voltage, applied to the [165]
control grid by the "Sensitivity" potentiometer from unit 6 through resistance R3-92, R3-94.

Upon the appearance of a target pulse and coincident range pulses, a negative pulse with an amplitude of around 25v passes to the grid of L3-19. A positive expanded pulse, the amplitude of which reaches $80 \div 100$v, appears at the anode of the tube. This pulse is applied to the grid of L3-19a and charges capacitance C3-64. This capacitor discharges through R3-92, as well as through R3-94 and R3-95, which are in parallel with it. All these resistances have a large value, as a result of which the time constant of the discharge is incommensurably greater than the time constant of the charge.

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This leads to the fact that in the interval between pulses, C3-64 does not succeed in discharging, and the voltage in it increases.

The increase in voltage at the cathode of L3-19a decreases the bias at the control grid of L3-20b, the tube opens, and the relay triggers. Triggering of R3-1 causes triggering of the rest of the relays in the unit: R3-2 and R3-3. In the event that the target pulse fades out, relay R3-1 releases, and capacitors C3-67 (2 μf) and C3-83 (1 μf), located in the grid circuit of L3-8a, begin to charge slowly, from a -150v source, through resistances R3-140 and R3-60.

Therefore, when the target pulse fades out, the voltage at the grid of L3-8a decays slowly, and the relay releases only after approximately 1÷1.5 sec. [167]

Herein is achieved the possibility of tracking a fading target "by memory" (memory based on speed). Upon triggering of relay R3-3 1÷1.5 sec. after locking, capacitors C3-75 and C3-86 with a total capacitance of 0.1 μf, the other end of which is connected to the anode of integrator I, are connected to the grid of the first integrator through C3-85.

As a result of this, after connecting the "protection" relay, the anode-grid capacitance of integrator I increases to 0.04 μf. This makes the ranging system more persistent, i. e., insensitive to abrupt changes of speed. Besides this, the presence of a large integrator capacitance imparts to range-only radar the property

[redacted]

more precise tracking of a fading signal "by memory," which reduces considerably the effect of target fluctuation on the speed voltage.

A smoothing signal (-27 v) is applied to unit RB6-5 simultaneously with triggering of relay R3-3. Thus, relay R5-2 operates, and the persistence of the speed-analysis circuit increases, which reduces the effect of target fluctuation on the speed voltage.

[redacted]

k) Constructive Design of the Unit

(Figs. 69, 70, 71)

The block is constructed on an open rectangular chassis. There is a depression for the IF amplifier line in the right section of the chassis. Parts having the greatest heat resistance, like the tube and the transformer are arranged at the top and the resistors and capacitors are in the lower section along the perforated panels.

The space between the perforated panels is occupied by the pulse transformer, precision resistors, and the relay. The last are easily removed through the access to the tube panels. Arranged under the IF amplifier are the large components: oil-impregnated paper capacitors, the delay line, and control potentiometers. These parts are in the form of demountable units and are easily removed from the block during repairs. The housing has a large number of openings to facilitate the cooling.

The functional circuit of the first integrator is in the form of a separate air-tight highly moisture-resistant removable unit.

Dimensions of the unit: 300 x 152 x 160 mm.

Weight of the unit: 4.7 kg

VI. RECEIVER

23. Purpose and Make-up

The receiver of the range-only radar "Kvant" is used to amplify the detection pulses reflected from targets and to convert them into video pulses.

The receiver is made up of the following components:

1. Resonant ATR tube.

2. Receiver mixer.

3. Klystron local oscillator.

4. IF preamplifier.

5. Main IF amplifier.

6. Second detector.

7. Video amplifier.

8. Cathode follower.

9. Pulse and noise automatic gain control systems.

24. Description of the operation of the receiver with the aid of a functional flow chart

The functional chart of the receiver is given in Fig. 73.

The pulses that are reflected from the target enter from the antenna into the "reception-transmission" chamber of the antenna switch, where a resonant discharge tube L2-12 (RR-21) is used in the capacity of a discharge tube.

From the "reception-transmission" chamber the energy of the reflected signal enters the frequency-mixer chamber, where a crystal rectifier of the type D-403-V (D2-2) is used as a mixer. [P 173]

In the receiver mixer chamber the frequency of the reflected signal is mixed with oscillations of the heterodyne (klystron of the K-27 (L2-9) type).

After the mixing, a number of frequencies are formed, from which an intermediate frequency is separated on the load of the receiver mixer.

The load of the receiver mixer is the input circuit of the IF preamplifier (PUPCh).

Having passed the stages of the IF preamplfier, which uses tubes of the 6Zh1B (L2-1, L2-2)type, the signal reflected from the target enters the main IF amplifier, which uses L3-1, L3-2, L3-5 (6Zh1P), L3-3; and L3-4 (6Zh2P) tubes.

Amplified by the IF amplifier and detected by the second detector L3-6 (6Kh2P), the target signal, passing through the video amplifier LV-7 (6N3P) and the cathode follower, is fed to the time discriminator and the noise automatic gain control circuit.

The pulse automatic gain control and noise automatic gain control have a common outlet to stages of the main IF amplfier through the cathode follower L3-10a (6N3P).

During the transmission operation part of the energy of the main pulse enters through the attenuator into the IF amplifier mixer, where the oscillations of the klystron heterodyne also enter. The difference frequency pulse, according to which the AFC generates the control voltage fed [P 174] to the klystron heterodyne, is separated on the input circuit of the automatic frequency control.

The control voltage is maintained such that the frequency of the klystron heterodyne would be higher by an IF than the frequency of the magnetron.

25. Purpose of the intermediate frequency amplifier

The purpose of the IF amplifier is to amplify the IF signals which were obtained as a result of the conversion of the picked-up reflected signals in the crystal mixer to a level which will ensure the operation of the II detector along the linear portion of its response. The purpose of the II detector is to convert the IF pulses into video pulses which are further amplified by the video amplifier.

The IF amplifier is assembled with coupled circuits and consists of an IF preamplifier and a main IF amplifier.

Basic tactical-technical data of the IF amplifier in a complex with the II detector and the video amplifier [P 175]

a. The transmission band of the IF is not less than 4.5 mc.

b. The IF amplifier's amplification factor, defined as the ratio of the signal voltage at the II detector input to the signal at the IF amplifier input and for a noise level at the II detector of 0.7, is not less than 100,000.

v. Sensitivity is not less than 15μv.

g. The amplification irregularity of the transmission band is not greater than 15%.

d. The transmission factor of the video amplifier is 15.

26. Description of the operation of the IF preamplifier by a schematic diagram

Intermediate frequency preamplifier

(Fig. 73)

The IF preamplifier represents a two-stage amplifier employing tubes of the 6Zh1B (L2-1 and L2-2) type. At the point of entry to the IF preamplifier a two-circuit filter is connected by an L-type connection.

The L-type diagram of the IF preamplifier input circuit is chosen to obtain the smallest noise factor and the greatest amplification under a wide transmission band.

At the same time the L-type arrangement of the input circuit ensures a stable operation of the first tube of the IF amplifier during the change in klystron power.

The input circuit consists of the Tr2-1 autotransformer and the L2-1 [P 176] inductance. In addition, the Tr2-1 also represents inductance because its windings have the same number of turns for a coupling coefficient equal to one. Constructional realization of this inductance in the form of a transformer is brought about by the necessity of separating the current circuits of the crystal mixer and the leakage current of the first IF preamplifier tube.

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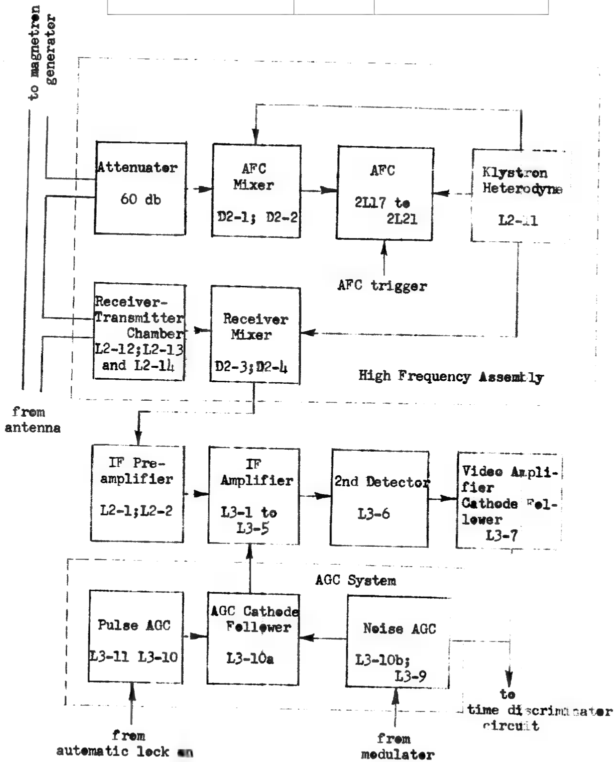

Fig. 73. Functional Flow Chart of the Receiver

The adopted L-type arrangement of the input circuit is equivalent to a coupled circuit which has on the mixer side inductance L_1 and capacitance C_1, and on the side of the input of the first tube, inductance L_2 and capacitance C_2.

The primary capacitance C_1 is the sum of the constructive capacitances — the mixer chamber and the coaxial cable which connects the mixer with the IF preamplifier input. The capacitance C_2 is the sum of the input capacitance of the first IF preamplifier tube and the capacitance of the mounting of the secondary circuit. Because the increase in capacitance C_2 causes a sharp increase in the noise factor, constructive measures are taken to reduce the mounting capacitances of the secondary circuit by selecting the most compact mounting.

The anode circuit of the first tube (L2-1) is loaded on the coupled [P 177a] circuit Tr2-2 with various Q-factors of the primary and secondary circuits.

The shunting resistors R2-2 and R2-3 are selected to obtain equal Q-factors for a stable amplification of the stage and a favorable pattern of frequency response.

The second amplifier stage consists of an L2-2 tube loaded on a single oscillatory circuit which consists of series-connected inductances L2-6 and L2-7 shunted by an R2-6 resistor. The capacitance of the circuit is the input capacitance of the tube and the capacitance of the unit combined.

The output circuit is connected with the input of the main IF amplifier through the capacitance C2-12 and a coaxial cable with a characteristic impedence of 75 ohms and a corresponding load at the input of the main IF amplifier.

An optimum correlation is selected between L2-6 and L2-7 to obtain a better transmission factor and a better pattern of the frequency response of the transition from the IF preamplifier to the IF amplifier.

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Due to the fact that the cathode current passes through resistances R2-1 and R2-5, self-bias is supplied to the grids of the amplifier tubes.

The capacitances C2-2 and C2-6 shunt the IF bias resistors and in this way exclude the negative feedback of the signal, increasing the amplification of the stages.

Power is supplied to the screen grids and plates through a series [P 181] decoupling filter consisting of inductance L2-4, resistance R2-7, and capacitances C2-4, C2-9, and C2-11.

In addition, the resistance R2-7 lowers the initial source voltage of 150 v to a value ensuring the operation tolerance of the tubes.

The filament of the tubes is also decoupled by a filter consisting of inductances L2-3 and L2-5 and capacitances C2-3, C2-7, and C2-10.

The IF preamplifier is tuned in an arbitrary sequence by turning the cores, the coupled circuits T2-1 and T2-2, and the inductance L2-6.

The core screws are led out on the tube side of the IF preamplifier subpanel.

The amplification of the IF preamplifier on an IF frequency is not less than 17 for a transmission band of not less than 6 mc.

The IF preamplifier frequency response is represented in Fig 74.

27. <u>Main intermediate frequency amplifier (UPCh)</u>

(Fig. 75)

From the IF preamplifier output, the signal enters the IF amplifier input, employing the miniature tubes 6Zh1P and 6Zh2P (L3-1 + L3-6).

To match the IF amplifier input with the characteristic impedance of the coaxial cable and the IF preamplifier output, a matching load of 75 ohms, which consists of two parallely connected resistors of 150 ohms each (R3-1 and R3-2), is connected to the IF amplifier input. [P 182]

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The capacitance C3-68 divides the automatic gain control circuit.

The coupled circuits Tr3-1 to Tr3-5 are connected to the plate circuits of L3-1 to L3-5 tubes with equal Q-factors.

The amplifying steps on the coupled circuits with equal Q-factors possess a more stable frequency response during a change of tubes and alterations of voltage supplies than signle circuit networks and other networks.

A necessary transmission band of each amplifying step (9 to 10 mc) is ensured by a selected relation between the windings of the plate and grid circuits and the shunting resistors.

All circuits are adjusted by changing the inductance by means of movable cores in arbitrary sequence. Along the central grid circuits of the L3-1 and L3-2 tubes a self-regulating amplification of the IF amplifier is carried out.

Regulating voltage is supplied from the automatic gain control grid which is located in the range finder device, through the decoupling filter consisting of filter cells Z3-1, Z3-2, R3-33 and capacitances C3-1, C3-6, and C3-31.

Along the circuits of the pentode grids of the L3-3 and L3-4 tubes the IF amplifier is blocked during transmission.

The blocking pulses are supplied from the modulator grid situated [P 183] in the RB6-2M transmitter-receiver unit.

Amplified to the necessary level, the IF signal is supplied to the diode detector which employs the left half of the L3-6 (6Zh2P) tube.

The frequency response of the basic IF amplifier, which is taken from the output of the detector for a signal of 100 μv at the IF input, is represented in Fig. 76.

The frequency response of the complete IF amplifier together with

the IF preamplifier is represented in Fig. 77.

The amplification of the main IF amplifier at IF is at least 10,000, the band width is at least 6 mc at an irregularity of not more than 10%.

The power supply of the screen grids and tube plates of the main IF amplifier is taken from the source +150 v, and to ensure the optimal operation of the tubes, part of the voltage is consumed across the resistance R3-30.

A multisectional filter, consisting of inductances L3-7 to L3-10 and capacitances C3-5, C3-10, C3-14, C3-18, C3-23, and C3-30, is used for decoupling the high frequency of the IF amplifier's screen grids.

The power supply of the tube plates is brought through the oscillatory circuit.

The tube filament circuits are also decoupled from each other by a filter consisting of inductances L3-1 to L3-6 and capacitances C3-3, C3-8, C3-12, C3-16, C3-20, C3-25, and C3-29.

The initial bias of the order of 2v is automatically supplied to the grids of the amplifier tubes due to the drop of voltage across the cathode [P 134] resistances R3-3, R3-6, R3-10, R3-15, and R3-19 as a result of current flow from the tubes. To eliminate the high frequency negative feedback, i.e., to increase the amplification, these resistances are blocked by capacitances C3-2, C3-4, C3-7, C3-9, C3-11, C3-15, C3-19, and C3-21.

28. Detector

(Fig. 78)

The intermediate frequency signals are detected by a diode detector occupying the left side of the L3-6 (6Kh2P) tube.

The main advantage of a diode detector is the linearity of its detection response, beginning with relatively small signal amplitudes, and the

absence of overload of the detector by strong signals.

From the Tr3-5 circuit the signal voltage of the intermediate frequency is supplied to the diode cathode.

A rectified voltage of the video signal is obtained on the resistance of the R3-25 detector load, and is then supplied to the video amplifier grid through the transient circuit C3-27 and R3-26.

This transient circuit, together with the right half of the L3-6 tube, limits incoming signals with respect to their duration, a process which is ensured by appropriate selection of the time constant.

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29. Video Amplifier

SPN 189

(Fig. 79)

Video pulses from the detector output are further amplified by a video amplifier which comprises the left half of tube L3-7 (6N3P).

Active resistance R3-23, having a value of 9.1 k Ω , is selected on the basis of conditions necessary to obtain a sufficient pass band (of the order of 2 Mc) and a gain of around 15 times is connected to the anode grid of the video amplifier.

To decrease the shunting action of the last stages, a video pulse from the video amplifier is fed to the cathode follower which comprises the second half of tube L3-7, from the load of which (R3-28) a signal is applied to the matching circuit. The amplitude characteristic of the video amplifier, taken from the output of the cathode follower, is depicted in Fig. 80.

30. Construction of the Receiver

The i-f amplifier is made in the form of two subpanels: i-f preamplifier subpanel (Fig. 81, 82), and i-f amplifier subpanel (Fig. 83, 84).

The i-f preamplifier subpanel is located in the receiver-transmitter unit, and the i-f amplifier subpanel, in the range unit.

Such a separation is made because the i-f amplifier must be placed in direct proximity to the crystal mixer to obtain a maximum signal-to-noise ratio. But because the receiver-transmitter unit where the crystal mixer is located is small

SPN 190 and it is not possible to put the i-f amplifier into it, the i-f amplifier is structurally divided into two subpanels: the pre- and the main i-f amplifier.

The pre- and main i-f amplifiers are connected to each other by h-f cable RK-156, which consists of two parts connected to each other be a hermetically sealed h-f plug.

The i-f amplifier and i-f preamplifier subpanels are attached to the chassis of the corresponding units by screws.

The input of the main i-f amplifier is made in the form of an h-f plug which is located at one end of the back edge of the subpanel, and leads to the front panel of the range unit.

The i-f preamplifier subpanel is supplied by a power supply cable.

The i-f amplifier power supply cable is teminated by seven-contact plug Sh3-1.

KTO type reference capacitors, which are connected to the chassis by means of nuts, are used in other circuits. These capacitors also serve as reference points for the rest of the components connected to them.

The screws for tuning the h-f circuits are inserted in the side of the tubes. The adopted construction of the circuits and their attachment to the chassis provide for tuning i-f amplifiers with the lids closed.

SPN 191 The tuning screws are attached by special springs, and after tuning are sealed with colored laquer.

To improve the operating stability of the i-f amplifier, the points of connection of the lids with the chassis are fitted with a gasket of special high-frequency electrical seal in the form of a special type of cord spliced with wire and a Monel metal strip, which improves the contact between the lis and the chassis.

The i-f preamplifier and i-f amplifier chassis are silver plated.

A special contact rack, which shorts the power lines of the last stages halfway to the first, is set in the middle of the subpanel to prevent galvanic connection of the first stage of the main i-f amplifier with the last.

The tube sereens, besides their basie function as shields, perform the role of tube holders, which is accomplished by special clamp springs which are part of the screen.

These springs, besides this, provide for reliable contact between the tube leads and the panel jacks.

A view of the i-f preamplifier and amplifier from the

mounting side are shown in Fig. 82 and Fig. 84.

31. Noise AGC of the Receiver (Noise AGC)

A constant voltage of set noises flows from the output cathode follower of the receiver to the coincidence tubes and then to the amplifier, peak detector, and the output tube of the automatic locking device.

SPN 192

The sensitivity of the automatic locking device is controlled at a definite noise level. When the environmental conditions or the supply voltages are altered, and also when the tube and component parameters change as a result of age, the level of receiver set noises may change.

An increase of noises may result in operation of the automatic locking device.

Such a false lock causes range-only radar to be completely faulty, since it excludes the possibility of locking on a target.

A decrease in the noise level is less dangerous; it leads to a certain loss of sensitivity of the automatic locking device. For example, a twofold decrease in the noise level relative to the initial level at which the automatic locking device was set results in a loss of approximately 3-5 db in the set sensitivity.

In connection with this a noise AGC circuit, the purpose of which is to maintain the constant noise level at the receiver

output when possible destabilizing factors act, is introduced into range-only radar.

Besides this basic requirement, the AGC system must be relatively insensitive to external interference and target pulses whose intensity can change over a wide range.

SPN 196 The noise AGC circuit, comprising tubes L3-9 (6Zh2P), L3-11b (6N3P), and L3-10a (6N3P) is shown in Fig. 85.

The first stage (L3-9) is an ordinary amplifier stage with resistors; the second stage (tube L3-11b) is a diode detector; the third stage (tube (L3-10a) is a cathode follower.

The circuit operates in the following manner:

Noise from the receiver output is applied to the input of the amplifier stage (tube (L3-9) through capacitor C3-36.

The amplified and phase-shifted noises are taken from resistor R3-42, which is the plate load of L3-9, and fed to L3-11b. The detected negative noise voltage then flows from the plate load R3-42 of tube L3-11b to the grid of cathode follower L3-10a and thence to the grids of the i-f amplifier control tubes.

In order to avoid the effects of pulse noises reflected from ground objects on the AGC circuit, the latter is blocked for a period of 50 ÷ 70 microseconds from the moment of emission of the main pulse.

The trigger pulse from unit 2 passes to diode L3-20b (right half), is expanded by the R3-98;C3-70 network, passes through capacitor C3-69 to the pentode grid of tube L3-9, and blocks the tube for a period of 50 to 70 microseconds.

Consequently, the noise AGC circuit does not function for a period of 50 to 70 microseconds during reception (see Fig. 86).

The original noise level at the output of the receiver channel is set by potentiometer R3-45 and corresponds to a certain negative voltage at the AGC output.

SPN 197 The noise level at the output of the receiver channel is set within limits of 5 $\div$ 7 v (0.5 of the cutoff limit).

When the noise level at the output of the receiver changes relative to the originally prescribed level, the AGC circuit changes its negative output voltage, leading to a change in the gain of the receiver and to the retention of the prescribed noise level at the output of the receiver channel.

In the event of the absence of manipulation of the circuit by a negative pulse when pulses reflected from ground objects are present, the AGC circuit increases the controlling voltage, which decreases both the noise level at the output of the receiver as well as the sensitivity of the set.

32. Pulse Automatic Gain Control of the Receiver (Pulse AGC)

Pulse automatic gain control is designed to maintain the pulse amplitude of the target at the receiver output at an

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approximately constant level when the intensity of the reflected signal at the input changes over a wide range. This is achieved by increasing the accuracy of determining the range to the target, since in the absence of such control the determined range would depend on the intensity of the reflected signal; thus, the range would be different for two aircraft (targets) of different size located exactly the same distance from the

SPN 202 receiver. There would also be an error in closing with the target. This is explained in Fig. 87.

The pulse AGC circuit operates only on the basis of a selective pulse; that is, a pulse which is locked on by the range unit. Such selection is necessary so that a decrease in the gain of the receiver does not occur in the presence of strong extraneous pulses (for example, noises reflected from nearby aircraft of the ground), which could lead to the impossibility of locking on a weak useful pulse reflected from the target.

The pulse AGC circuit (Fig. 88) operates in the following manner:

A positive pulse passes from the anode of the amplifier of the automatic locking device (L3-19, right half of the tube) through spacing capacitor C3-65 to the grid of the amplifier of tube L3-11 (6N1P). The performance of this amplifier (bias) is determined by the control "Pulse Amplitude" (potentiometer R3-65).

A negative pulse taken from load R3-52 is detected by the normally closed right diode of tube L3-10 and, from its load and the stretching capacitance (R5-47, C3-39), is applied in the form of a d-c voltage to the grid of the cathode follower (left triode of tube L3-10) and thence to the control grids of the i-f amplifier control tubes.

The change in bias at the control grid of tube L3-11a leads to a change in the amplitude of the video pulse at the output of the receiver channel. The magnitude of the amplitude at the output of the receiver channel is usually maintained to within 0.9 of the cutoff level.

CPN 202

SPN 203

VII. POWER SUPPLY RB6-4

33. Function

This unit is intended to supply the units of the "Kvant" range-only radar with rectified, stabilized voltages of:

+ 300 v, + 200 v, + 150 v, and - 150 v.

34. Functional Diagram

The functional diagram of the power supply consists of seven basic assemblies and is shown in figure 89.

When a ~ 115 v, 400 cps voltage is applied to the primary windings of the transformers, voltages are taken from the secondary windings and fed to rectifiers designed as bridge circuits with crystal diodes type D7Zh. After this, the rectified pulsating voltages are fed to electronic voltage stabilizers.

The constant voltages are fed from the output of these stabilizers to the plug connector of the unit.

35. Schematic Diagram of the Unit

A schematic diagram of the unit is shown in figure 90. The unit is supplied by a ~ 115 v, 400 cps a-c voltage.

Rectifier and Stabilizer, + 300 v

The rectifier which supplies the electronic stabilizer with + 300 v is built on a bridge circuit with crystal diodes D7-Zh.

SPN 204 Four crystal diodes are connected to each arm of the bridge.

In order to decrease the pulsations of the rectified voltage, a capacitor C4-1 equal to 2 microfarads is placed at the output of the rectifier.

The circuit operates in the following manner.

When an a-c voltage (~ 115 v, 400 cps) is applied to the primary

winding of the transformer, a voltage of ~ 390 v is taken from the secondary winding 3-5 and applied to the bridge.

When terminal 3 of secondary winding 3-5 of transformer Tr4-2 is positive with respect to terminal 5, D4-17, D4-18, D4-19, D4-20 and D4-25, D4-26, D4-27, and D4-28 function.

At the next moment, when terminal 5 of the secondary winding is positive, arms D4-16, D4-15, D4-14, D4-13 and D4-24, D4-23, D4-22, and D4-21 function.

Thus, the rectified current passes through the load through both half periods in one direction.

There are no filters in this rectifier. This is explained by the fact that the property of the electron-ion voltage stabilizer circuit is used as a filter.

Stabilizers of this type have instantaneous reaction to changes in the voltage of an external power supply, which is the rectifier, while maintaining at the same time a steady output voltage.

SPN

Further, the rectified voltage is applied to an electronic voltage stabilizer which is designed as a series-connected circuit with a control tube (L4-1) type 6P1P and a two-stage d-c amplifier (tube L4-4) (6N2P), with a reference voltage supplied by voltage stabilizer SG3S (L4-10), which is common for all electronic stabilizers of the unit.

Let us assume that, due to an increase in voltage of the ~ 115 v 400 cps supply network, or as a result of a decrease in current consumption, the voltage at the output of the electron-ion stabilizer increases. This leads to an increase in the divider current, consisting of resistors R4-6, R4-7, R4-8, and R4-9, to a decrease in negative bias at the control grid of the right half of tube L4-2, and, accordingly, to an increase in its anode current and a drop in voltage across resistor R4-5. In turn, the increased voltage drop at resistor R4-5 causes a decrease in negative bias in the left half of tube L4-2 and an increase in its anode current, and, accordingly, to an increase in the voltage drop across resistor R4-4. The voltage drop at resistor R4-4 is in no way different than the bias of control tube L4-1, which determines its internal resistance.

The internal resistance of tube L4-1 increases, causing an increase in the value of the voltage applied to it and a decrease in the voltage at the output of the stabilizer.

SPN 206

Thus, the resulting increase in voltage will be compensated. With a decrease in the voltage of the ~ 115v, 400 cps supply network, or with an increase in current consumption, the voltage at the output of the electronic stabilizer will be stabilized in a similar manner.

Resistors R4-2 and R4-88 serve to limit the current through tube L4-1 (6P1P).

Capacitor C4-2 serves to increase filtering of the output voltage.

Capacitor C4-3 is a decoupling capacitor.

Fuse Pr4-2 serves to protect tubes L4-1 and L4-2 and transformer Tr4-1.

Rectifiers and Stabilizers, + 200 v and + 150 v

The rectifier which supplies the + 200 v and + 150 v electronic stabilizers is assembled in a bridge circuit with crystal diodes D7Zh. Three crystal diodes are connected to each arm.

The principle of operation of the rectifier is analogous to that described above.

The 200 v electron-ion voltage stabilizer uses tubes L4-3, L4-4, and L4-5a.

The 150 v electron-ion voltage stabilizer uses tubes L4-6, L4-7, and L4-5b.

SPN 207

Rectifier and Stabilizer, - 150 v

The rectifier which supplies the - 150 v electronic stabilizer is also designed as a bridge circuit with D7Zh crystal diodes. Each arm is connected to 2 diodes.

Unlike the positive voltage rectifiers examined above, the voltage for the stabilizer is taken from the "minus" side of the bridge circuit in this case.

Tube L4-8 is used as a regulating tube, L4-9 as a control tube, and L4-10 as the reference voltage source.

The principle of operation and functions of the individual ele-

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ments of the circuit are analogous to the above-described circuits with only one exception -- in the negative-voltage electron-ion stabilizer, a decrease in supply voltage causes a decrease in negative bias as the control tube.

Resistor R4-32 is the load resistance of voltage stabilizer L4-10.

Capacitor C4-11 serves to decrease pulsations of the voltage stabilizer as well as possible self-excitations of the circuit.

SPN 208

36. Construction of the Unit

The power supply unit is built in a separate mounting frame having a shock-absorbing frame and housing.

A general view of the unit is given in figures 91, 92, 93, and 94.

The more intense sources of heat, namely tubes 6P1P (6 tubes), 6N2P (3 tubes), SG3S (1 tube), and the vitrified resistor are placed in a section adjacent to the front panel. The capacitors are separated from the forward section by an insulating partition.

On the front panel of the unit (fig. 91) is a fuse box and a cable with a 9-pin connector plug.

At the rear wall of the unit (fig. 91) on a brace are the crystal diodes, which are separated from the capacitor section by another screen made of textolite.

Also on the rear wall of the unit are the control units for + 300 v, + 200 v, + 150 v, and - 150 v.

The shock-mounted frame is mounted to the housing with the aid of locator pins and two knurled hinge nuts.

The dimensions of the unit are: 284 X 150 X 168 mm.

Weight of the unit: 4 kg.

SPN 212

VIII. Speed Unit RB6-5

37. Function

This unit is designed to automatically determine the relative

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speed of the target and to feed the corresponding voltage to the sight computer ASP-5NM and to the comparator unit K-8.

38. Basic Technical Data of the Unit

a. Rule for speed voltage output in mode "A":

$$U_{sp}\ (v) = -\ 0.1\ V\quad m/sec$$

in mode "B":

$$U_{sp}\ (v) = -\ 0.04\ V\quad m/sec$$

Speed is positive during approach.

b. Maximum statistical error in determining speed:

in mode "A" -- no greater than ± 10 m/sec

in mode "B" -- no greater than ± 35 m/sec

c. Target speed voltage is presented in a speed range from - 100 m/sec to + 400 m/sec.

d. Dimensions of the unit: 92 X 92 X 170 [mm]

e. Weight of the unit: 1.4 kg.

39. Functional Diagram of the Speed Unit (Fig. 95)

The range voltage U_d from unit RB6-3, taken from cathode follower L3-22b through filter R5-13, C5-9, is applied to differentiating circuit C5-1, R5-1.

SPN 214 A voltage appears at the output of the differentiating circuit which is proportional to the rate of change of the voltage at the input of the circuit. Since a range voltage is applied to the input, the output will provide a voltage which is proportional to rate of approach or withdrawal of the target (fig. 96).

The magnitude of this voltage is small and must be amplified to the required value. Since the speed voltage is constant or changes slowly, a d-c amplifier must be used for this purpose.

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The presence of drift makes it impossible to use ordinary d-c amplifier circuits, and, therefore, a special amplifier was designed.

The amplifier consists of a balance converter based on tubes L5-1 and L5-2 (type 6S6B), a phase detector based on tube L5-3 (6Zh1B), and a cathode follower -- tube L5-4, type 6S6B.

The amplifier encompasses a feedback circuit which increases its operating stability and provides a constant amplification factor. The value of this amplification factor is determined by the feedback circuit and is equal to 8.

The speed voltage passes from the output of the phase detector through cathode follower L5-4 to the sight computer ASP-5NM and to the comparator unit K-8.

SPN 216 Capacitor C5-8 is used to smooth speed voltage fluctuations. During the setup time of the speed voltage, equal to 1 second, capacitor C5-8 is disconnected. If this were not the case, the setup time would be considerably greater.

40. Description of Schematic Diagram (Fig. 97)

A voltage proportional to the range to the target is applied through filter R5-13 and C5-9 to the differentiating circuit C5-1 and R5-1, at the output of which is produced a voltage proportional to the speed of the target. This may be explained by the fact that, at the output of such a circuit, the voltage is expressed by the relationship:

$$U_{out.} = \frac{dU_{in.}}{dt} RC$$

This condition will be satisfied within a time corresponding to $(3 \div 4)$ RC (fig. 96); since, when the station is operating in mode "A"

$$U_{in.} = 95 - \frac{D}{20} \quad ; \text{ then,}$$

$$\frac{dU_{in.}}{dt} = -\frac{1}{20}\frac{dD}{dt} \quad ;$$

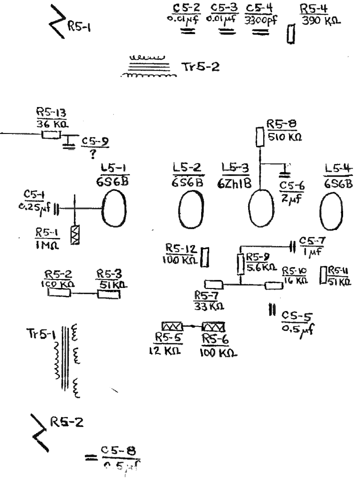
correspondingly:

$$U_{out.} = -\frac{1}{20} RC \frac{dD}{dt} \quad .$$

SPN 217 Since: $RC = 1 \cdot 10^{6} \cdot 0.25 \cdot 10^{-6} = 0.25$ sec,

$$U_{out.} = \frac{1}{80}\frac{dD}{dt}$$

Function	Ter no.
ground	1
~115 v	2
~115 v common	3
+ 27 v	4
U range	5
speed scale	6
+ 200 v	7
lock-On circuit	8
speed zero	9
speed zero	10
track.	11
U speed	12
	13
- 150 v	14
	15
	16
	17



Pos. desig.	GOST-VTU specs.	Designation and type	Rating	No.
R5-1	VP4675006	Res.PTU-1-1MΩ ± 1%	1 MΩ	1
R5-2	OZh0467003TU	Res.MLT-0.5-100kΩ-II-B	100 kΩ	1
R5-3	OZh0467003TU	Res.MLT-0.5-51kΩ-II-B	51 kΩ	1
R5-4	OZh0467003TU	Res.MLT-0.5-390kΩ-II-B	390 kΩ	1
R5-5	VP4675004	Res.PTU-0.5-12kΩ ± 1%	12 kΩ	1
R5-6	VP4675004	Res.PTU-0.5-100kΩ±1%	100 kΩ	1
R5-7	OZh0467003TU	Res.MLT-1-33kΩ-II-B	33 kΩ	1
R5-8	OZh0467003TU	Res.MLT-0.5-510kΩ-II-B	510 kΩ	1
R5-9	OZh0467003TU	Res.MLT-0.5-5.6kΩ-II-B	5.6 kΩ	1
R5-10	OZh0467003TU	Res.MLT-0.5-16kΩ-II-B	16 kΩ	1
R5-11	OZh0467003TU	Res.MLT-1-51kΩ-II-B	51 kΩ	1
R5-12	OZh0467003TU	Res.MLT-0.5-100kΩ-II-B	100 kΩ	1
C5-1	UB0461015TU	Cap.MPG-P-250-0.25-I	0.25 µf	1
C5-2	UB0462017TU	Cap.BGM-T-1-0.01µf-I	0.01 µf	1
C5-3	UB0462017TU	Cap.BGM-T-1-0.01µf-II	0.01 µf	1
C5-4	UB0462017TU	Cap.BGM-T-1-3300pf-II	3300 pf	1
C5-5	OZh0462022TU	Cap.MBGP-1-200-A-0.5µf-II	0.5 µf	1
C5-6	OZh0462022TU	Cap.MBGP-1-200-A-2-II	2 µf	1
C5-7	OZh0462022TU	Cap.MBGP-2-200-A-1-II	1 µf	1
C5-8	OZh0462022TU	Cap.MBGP-2-400-A-0.5-II	0.5 µf	1
C5-9	OZhO (?)	Cap.BGM-2-400-(?)	(?)	1
L5-1	UTU0131655	Radiotube 6S6B		1
L5-2	UTU0131655	Radiotube 6S6B		1
L5-3	UTU0131655	Radiotube 6Zh1B		1
L5-4	UTU0131655	Radiotube 6S6B		1
R5-13	(?)	Res. (?)	36 kΩ	1
Tr5-1	GYa4714034	Transf. (?anode cur?)		1
Tr5-2	G(?)-8?0-000	Transformer		1
R5-1	Yu1718121	Relay RSM-2		1
R5-2	Yu1718121	Relay RSM-2		1

Key to figure 97.

The given value of speed is determined by the relationship:

$$U_{sp.} = -\frac{1 d\mathcal{D}}{10 dt}$$

This also explains the need for an amplifier with an amplification factor

$$K = \frac{U_{sp.}}{U_{out.}} = 8.$$

When the station is operating in mode "B"

$$U_{in.} = 195 - \frac{\mathcal{D}}{50},$$

$$\frac{dU_{in.}}{dt} = \frac{1 d\mathcal{D}}{50 dt}$$

Accordingly:

$$U_{out.} = -\frac{1}{50} RC \frac{d\mathcal{D}}{dt}$$

Since the time constant has not changed,

$$RC = 0.25 \text{ microfarad}$$

$$U_{out.} = -\frac{1 d\mathcal{D}}{200 dt}$$

SPN 218 Since the amplification remains as before, the speed scale in the "B" mode will equal:

$$K = \frac{U_{sp.}}{U_{out.}} = 8$$

$$U_{sp.} = U_{out.} 8 = -0.04 \text{ V}$$

An L-shaped filter $R_{13} C_9$ is introduced for the purpose of eliminating extraneous influences found in the range voltage.

The computing circuit is also a d-c amplifier with an amplification factor equal to 8.

The necessity of obtaining a linear characteristic and stable operation of the amplifier led to the use of a converter at the output of circuit L5-1 and L5-2 to convert the d-c voltage to 400 cps signals and to the realization of a basic gain in alternating current. Subsequent reverse conversion is accomplished by a phase detector (L5-3).

In the search mode the control grid of L5-1 of the balance converter is connected to ground and the voltage at the grid is equal to

zero. The latter is also the case when locking on a stationary target, when the range voltage does not change.

The voltage at L5-2 is also equal to zero, while the currents flowing through the right and left windings of pulse transformer Tr5-2 are equal in value. There is no a-c voltage at the output winding of Tr5-2.

SPN 220 An a-c voltage (100 v, 400 cps) is applied to the screen grid of phase detector from a special winding of transformer Tr5-1. During the positive half of the voltage cycle at the screen, the tube opens and current flows through the anode circuit. During the negative cycle, the tube is closed and current ceases to flow.

Capacitor C5-6 smooths the voltage pulsations at the anode. The operating conditions of the tube are selected in the given case so that the voltage at the anode of L5-3 is equal to zero (this is possible since the cathode of L5-3 is supplied by the - 100 v source). This voltage is applied to the grid of cathode follower L5-4. A zero voltage is fed from the output of L5-4 through feedback divider R5-6, R5-5, and R6-6 to the grid of L5-2 and to the sight circuits.

When tracking an approaching target the range voltage increases. The derivative of this increasing value is positive and, therefore, the voltage at the left grid of the balancing amplifier increases to a certain positive value. This value will depend on the closing speed.

Due to the increase in voltage at the grid, the current in tube L5-1 increases in comparison with the current in the right half. These currents cease to compensate for each other and an a-c signal appears at the output of Tr5-2. The middle point of Tr5-2 is supplied by an a-c voltage (200 v, 400 cps) from transformer Tr5-1. The a-c voltage from the output of Tr5-2 is applied to the grid of phase detector L5-3.

SPN 222 As may be seen from figure 98, the phases of the signal voltage and the voltage at the screen grid of L5-3 are, in this case, in opposition. This leads to the fact that, during the positive half of the screen voltage cycle, the voltage at the control grid decreases and the anode current of the tube also becomes less, while the voltage at the anode increases.

The increase in voltage at the anode is transmitted through L5-3 to the sight. In tracking a receding target the voltage at the control grid of L5-1 is negative and the phase of the signal voltage at L5-3 coincides with the phase of the reference voltage.

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The anode current of L5-3 increases and the voltage at the anode and at the output of the circuit drop. The values of the voltage at the output become negative. In order to obtain a linear transfer characteristic, the entire circuit encompasses a feedback circuit in the form of divider R5-6, R5-5, and R6-6.

Due to the high "internal" gain, the transfer constant of the entire amplifier is determined in the basic feedback circuit by:

$$K = \frac{K_o}{1 + K_o\beta} \quad ,$$

where: K - the transfer constant of the amplifier with feedback;

K_o - the transfer constant of the same amplifier without a feedback circuit;

β - the feedback factor.

In our case $K_o \approx$ 1,000.

SPN 223

$$\beta = \frac{R5\text{-}5 + R6\text{-}6}{R5\text{-}4 + R6\text{-}6 + R5\text{-}5} \approx \frac{1}{8}$$

Thus:

$$K = \frac{1{,}000}{1 + \frac{1{,}000}{8}} \approx 8 \quad .$$

Since the scale (slope of the characteristic) of the speed voltage depends on the value of the transfer constant, it may be controlled by changing β by means of R6-6.

Null control is accomplished with the aid of variable resistor R6-10, which balances the currents in L5-1 and L5-2.

To decrease speed voltage fluctuations, which will occur because of fluctuations in range voltage, the smoothing filter R5-6 and C5-8 is introduced into the feedback circuit.

The principle of operation of the filter is based on the fact that, in the given case, the feedback factor for the high-frequency components of speed voltage will be considerably greater than 8, since the equivalent resistance of C5-8 will decrease with an increase in frequency and will become less than R5-6.

Accordingly, the amplification factor of the amplifier for high-frequency components decreases and fluctuations do not pass to the

output of the circuit.

A delay in switching on the filter is necessary in order to decrease the setup time of the speed voltage.

SPN 224

In the differentiating circuit RC = 0.25 sec. Without considering the filter, the setup time is 0.75 ÷ 1 sec., and with the filter it reaches greater values (RC of the filter = 0.05; 4RC = 0.2 sec, considering gain, $RC_{equiv.} = 8 \times 0.2 = 1.6$ sec).

In the search mode a search voltage will appear at the input of the differentiating circuitwhich will fluctuate between 25 and 185 volts. When locking-on is achieved, the voltage will correspond to the range to the target.

In order that the unit will not be overloaded by large voltages while in the search mode (scanning rate ≈ 3,000 m/sec), the grid circuit of the input tube of the balance converter L5-1 is connected to ground by contacts 1;2 of relay R5-1 and opens only at the moment of lock-on, while, simultaneously, contacts 3;4 of the same relay send a lock-on signal to the sight ASP-5NM.

41. Construction

The speed unit has a cylindrical shape with a maximum diameter of 92 [mm] and a length of 170 [mm]. The unit is dust- and moisture-proof.

SPN 225

Located on the front panel of the unit are tubes with rubber seals protected a perforated metal casing, and the connecting cable with hermetically sealed bushings located under the protective face plate and shield. (Fig. 99).

Perpendicular to the front panel is the mounting frame which has cutouts of complex shape.

On the top of the mounting frame (fig. 100) are located: the power transformer, a type RSM relay, an interstage transformer TI-87-0-000, type MGBP capacitors, type MPGP capacitor for the differentiating circuit, and a wiring panel.

Precision resistors are located on the bottom of the mounting frame (fig. 101).

The unit has a cylindrical housing with a sealing flange.

Sealing is accomplished through the use of a rubber gasket between the front panel and the flange of the housing. The unit has removable holding straps.

The weight of the unit is 1.4 kg.

SPN 228

IX. Control Panel (K-6)

42. Function of Control Panel

The control panel is the center of all the basic controls of the set and is the control point from which is measured the voltage at the "sensitivity" potentiometer of the automatic lock-on device. In addition, the "time relay" which serves to delay cutting in of the high voltage in unit RB6-2M, and the circuit switching relay for the operating modes of the set are also located on the control panel.

43. Schematic Diagram of Control Panel

A schematic diagram of the control panel is given in figure 102.

Fuse PR6-2 (5 a) is located in the 115 v, 400 cps circuit-breaker. When the current consumed by the sight or the radar in the 115 v, 400 cps circuit exceeds 5 amperes, fuse PR6-2 blows the circuit-breaker in the network.

Fuse PR6-1 (10 a) is located at the breaker for the 27 v circuit. When radar or sight current exceeds 10 amperes in this circuit, fuse PR6-1 breaks the circuit.

The "AFC Gain" potentiometer serves to regulate the initial bias at the control grid of the i-f amplifier tube of the AFC circuit. Capacitor C6-2 blocks high-frequency current from resistor R6-3.

SPN 229

The "Sensitivity" potentiometer R6-13 and resistors R6-12 and R6-14 create the necessary level at which the automatic lock-on circuits begin to operate (see the description of the automatic lock-on circuit of range unit RB6-3).

The "Range Zero" potentiometer (R6-15) and resistor R6-16 comprise a divider from which is taken the voltage for regulating range zero in the "Fast Sawtooth" generator.

Potentiometer R6-11 is located in the grid control circuit of the

fast sawtooth generator and regulates the range "Scale" in mode "A". Potentiometer R6-17 regulates the range "Scale" in mode "B".

Potentiometer R6-6 is located in the feedback network of the circuit which provides the speed voltage and serves to regulate the "Speed Scale."

Potentiometer R6-10, resistors R6-8, R6-9, and capacitors C6-3, C6-4 are placed in the cathode circuits of the amplifier used in the speed processing circuit. Potentiometer R6-10 regulates the speed "zero."

The purpose of relays R6-1 and R6-2 is to delay cutting in of the high voltage for the period of time necessary to warm-up the modulator in the receiver-transmitter unit. Relay R6-1 is a thermorelay; R6-2 is an electromagnetic relay.

SPN 230 A voltage of + 27 v is fed to the winding of R6-2, which closes the high-voltage circuit (contacts 7-12), through the normally open contacts of relay R6-1 (contacts 3-4).

When the toggle-switch "stantsiya" [set] on the sight is switched on, a voltage (~ 115 v, 400 cps) is applied to unit RB6-4, where the supply voltages of the set are produced. A - 150 v voltage is fed to thermorelay R6-1. The operating time of the thermorelay is 2.5 to 3 min. When the relay operates, contacts 3-4 close and + 27 v is applied to the winding of relay R6-2, operating this relay and closing contacts 7-12.

After this, the high voltage may be turned on by means of toggle-switch "Radio-Optics" located on the control panel of the sight. When this switch is turned on, a voltage of ~ 115 v, 400 cps is applied to the primary winding of the high-voltage transformer in unit RB6-2 and signals that the high voltage is on.

Fuse PR6-3 (0.5 a) is located in the high-voltage switching circuit. If current consumption in this circuit exceeds 0.5 ampere, the fuse blows and the circuit is opened.

Relay R6-3 serves to switch the radar circuits between modes "A" and "B". In mode "A", when the relay is de-energized, the range voltage is applied to the sight according to the rule:

$$U_d = 195 - \frac{D}{20}$$

(contacts 11 and 6), the circuit R6-17, R6-18, R6-19 is shorted (con-

tacts 9-1), and the ferrite switch switches operation of the antenna to wide beam (contacts 12-8 and 10-3).

SPN 231 With the presence of a mode "B" signal, relay R6-3 operates and disconnects the range voltage from the sight circuits, applying it to unit K-8 (contacts 11-5). The network R6-17; R6-18; R6-19 is connected in series with the potentiometer "Range Scale A," following the rule:

$$U_d = 195 - \frac{D}{50}$$

Simultaneously, the ferrite switch switches the antenna to narrow beam. Resistor R6-21 (100 ohms)serves to measure the currents of the ferrite switch in moth modes.

Resistors R6-7 and R6-20 provide the required magnetization current for the ferrite in both modes.

44. Construction of Control Panel

(Figures 103, 104)

The control panel is made of a box chassis and a housing which is fastened to the chassis by 5 screws. On the front panel of the unit are the following:

SPN 232

a. "Sensitivity" potentiometer
b. "Range Zero" potentiometer
c. "Range Scale A" potentiometer
d. "Range Scale B" potentiometer
e. "AFC Gain" potentiometer
f. "Speed Zero" potentiometer
g. "Speed Scale" potentiometer
h. "115 v, 5 a" fuse
i. 115 v, "V.N." [High-Voltage], 0.5 a fuse
j. "27 v", 10 a fuse

At the bottom of the unit is a cable which connects to an intermediate cable with the aid of a type "R" connector with 28 contacts.

Dimensions of the unit: 170 X 110 X 78 mm.

Weight of the unit: 1.5 kg.

SPN 235

X. Comparator Unit (K-8)

45. Function

The comparator is designed for:

a) Supplying a present-range-to-target voltage to the pilot's range indicator "UD-1" following the rule:

$$U_{range} \text{ (volts)} = 3.75 \text{ D (km)}.$$

b) Automatically comparing present range to target with the permissible launch range of homing missiles K-13 and supplying a trigger signal to the green light "Launch" located on the pilot's instrument panel.

c) Signalling when withdrawal-from-attack range has been reached (the red light "Pull-Out" located on the pilot's instrument panel).

d) Feeding a d-c voltage (+ 27 v) to VRD-2A.

Switching the circuits of the unit to operating status is accomplished automatically by lock-on and mode signals.

46. Basic Technical Data of the Unit

a) The operating range supplied to the pilot's range indicator "UD-1": 0 ÷ 8 km.

b) The relationship of present-range-to-target voltages supplied to the pilot's range indicator is given in table #1.

SPN 236

Table #1

D [range] (m)	U_d (v)
0	0
1,000	3.75
2,000	7.50
3,000	11.25
4,000	15.00
5,000	18.75
6,000	22.50
7,000	26.25
8,000	30.00

c) The relationship of withdrawal-from-attack signal (pull-out signal) to range-to-target:

$$1{,}000 \text{ m} \leq D_{\text{pull-out}} \leq 1{,}150 \text{ m}$$

d) Dimensions of the unit: 159 X 109 X 90 [mm].

e) Weight of the unit: 1 kg.

47. Description of Operation of Unit According to Functional Diagram

A functional diagram of the unit is given in figure 105.

The permissible range voltage ($U_{\text{д per}}$) from the output of VRD-2A and the present range voltage ($U_{\text{д}} = 195 - \frac{D}{50}$) are fed through the cathode follower to the comparator tube L8-2, which is closed in the initial state.

The moment of launching the missile is determined from the equality:

$$D_{\text{pres}} \leq D_{\text{per}}$$

SPN 237 When $U_{\text{д pres}} \leq U_{\text{д per}}$, tube L8-2 opens and the voltage at its anode drops suddenly. At the same time, the voltage at the grid of the tube of relay L6-3a decreases, the tube closes, and the relay, which is connected to the anode of the tube by its normally closed contacts, turns on the green light "Launch."

The "pull-out" circuit consists of a precision divider to which is fed, on the one hand, the present range voltage and, on the other, a negative voltage of - 150 v.

The voltage from the divider is applied to the grid of tube L8-3b, to the anode of which is connected the pull-out signal relay.

The tube is closed in its initial state.

With the arrival of a lock-on signal and when the range voltage has reached a value equal to a distance of 1,000 + 1,150 m, the tube opens and the relay operates. The "Pull-Out" light on the pilot's instrument panel turns on.

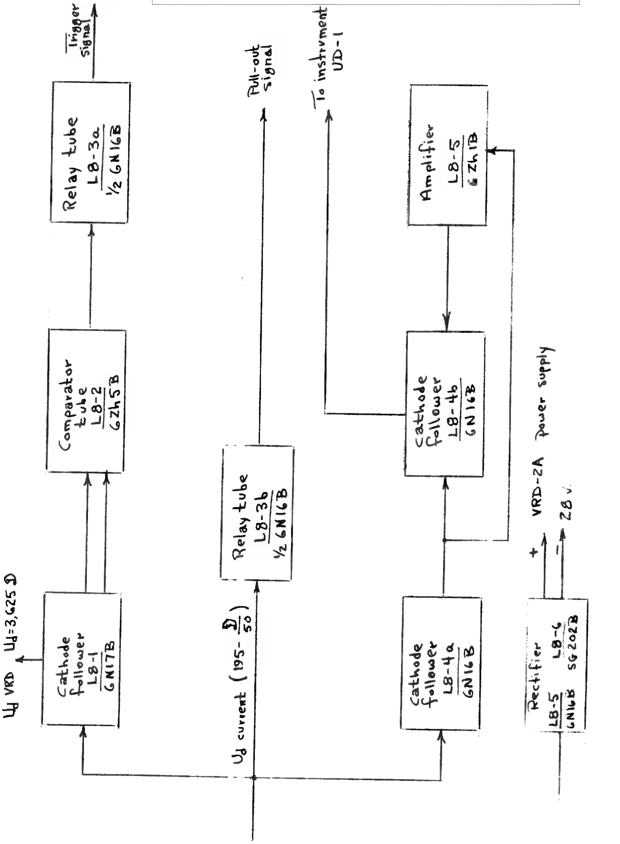

Fig. 105 Functional diagram of unit K-8.

The circuit used to convert the present range voltage to the voltage which is applied to the pilot's range indicator consists of an operational amplifier in a negative feedback circuit.

The present range voltage, which is applied to the input of the operational amplifier, changes from 195 v to 35 v with changes in range from 0 to 8 km; that is, it changes according to decay law.

SPN 238 In connection with the fact that the full deflection current of the pilot's range indicator is equal to 10 ma and the resistance of the instrument is equal to 3 kilohms, it is necessary that the voltage in the indicator change within limits of 0 to 30 v with changes in range (D_{pres}) from 0 to 8 km; that is, according to an increasing law.

Conversion of the law to a range voltage scale is accomplished by the operational amplifier which sends a range voltage in the necessary scale to the pilot's indicator.

48. Description of Operation of Unit According to Schematic Diagram

A schematic diagram of the unit is given in figure 106.

When the set is operating in mode "A", relay R8-5 is in the released position. In this case the circuit of the range instrument is open.

In the absence of a lock-on signal, relays R8-3, R8-4 are in the released position.

The range instrument and "Launch" signal circuits are open and part of the divider of the pull-out circuit is connected to ground.

In the presence of a mode "B" signal and a lock-on signal, the relay operates and the circuit becomes operative.

The basic function performed by the unit is the comparison of two voltages:

$U_{д\,pres}$ -- supplied by the range unit, and $U_{д\,per}$ -- taken from potentiometer VRD-2A.

The present range voltage in the scale $U_д = 195 - \frac{D}{50}$, taken from

SPN 240 unit RB6-3, flows through cathode follower L8-1 (a) to the precision divider R8-33, R8-34, R8-35, to the other end of which flows (also through the cathode follower L8-1 (b)) the permissible range voltage taken from potentiometer VRD-2A. The control grid of tube L8-2, a pentode with high transconductance and a high-resistance anode load, is connected to the middle point of the divider; therefore, the slightest change in the voltage at the grid with respect to the cathode will cause a sharp change in the potential of the anode.

Tube L8-3a is open in its normal state.

The operating condition of tube L8-2 is selected so that when voltage $U_{d\ pres}$ is greater or equal to $U_{d\ per}$, the tube opens and a voltage is suddenly applied to its anode. The drop in voltage through divider R8-7, R8-8 is applied to the grid of tube L8-3a. The tube closes and de-energizes relay R8-1. The green light "Launch" on the pilot's instrument panel is turned on. The withdrawal-from-attack circuit consists of a precision divider and tube L8-3b; the anode of this tube is connected to relay R8-2. One side of the divider is supplied by a voltage of - 150 v and the other side by the present range voltage.

In its initial state, when there is no lock-on signal, part of the divider is grounded through contacts 3 and 4 of relay R8-4, and a negative voltage from R8-13 is applied to the grid of L8-3b, closing the tube to current flow.

SPN 241 With the arrival of a lock-on signal, relay R8-4 operates and the divider is disconnected from ground.

Now a range voltage flows to the divider. When the range voltage equals 175 ÷ 172 v [sic], corresponding to a range of 1,000 - 1,150 m, the potential at the control grid of L8-3b increases until the tube opens and relay R8-2 operates. The red light "Pull-Out" on the pilot's instrument panel is turned on.

In order to check for errors in the comparator circuit and the pull-out range circuit during ground checkout, a calibration signal is taken from the control instrument KPK. In this case, relays R8-7 and R8-6 will operate and send voltages from KPK to the input of the comparator circuit, simulating permissible and current range voltages.

The circuit which supplies the range voltage to the pilot's range indicator is designed with tubes L8-4 and L8-5. The true range voltage changes from 195 to 35 v; that is, the voltage drop will equal 160 v.

[redacted] 50X1-HUM

The voltage applied to the range indicator must change from 0 v to 30 v; that is, the voltage drop to the indicator is approximately 5 times less.

This condition determines the scale of the operational amplifier, which is set by the ratio of the arms of divider R8-16, R8-17.

For precise adjustment of the scale, the divider is connected to potentiometer R8-16, the center point of which is connected to the grid of tube L8-5.

SPN 242 The operational amplifier represents a servo system with strong negative feedback.

Tube L8-5, a pentode with high gain, picks up the smallest changes in voltage at the center point of potentiometer R8-16 and, after amplification, feeds the voltage through divider R8-20, R8-21 to the grid of cathode follower L8-4b.

A change in voltage at the cathode of L8-4b causes a change in the voltage drop across R8-17 so that the voltage at the center point of potentiometer R8-16 will always equal zero. As an example, let us assume that the voltage at the cathode of L8-4a decreases; then the potential at the control grid of L8-5 decreases, the voltage at the anode of this tube increases and is fed through divider R8-20, R8-21 to the cathode follower L8-4b. The increase in voltage at the cathode of L8-4b causes an increase in the voltage drop across R8-17 so that the voltage at the center point of potentiometer R8-16 will equal zero.

On the other hand, if the voltage at the cathode of L8-4a increases, the voltage at the cathode of L8-4b decreases to a corresponding degree and the voltage at the center point of potentiometer R8-16 will again equal zero.

The range voltage in the necessary scale is fed to the pilot's range indicator.

SPN 243 Tubes L8-6 and L8-7 form a rectifier with electronic stabilization for supplying VRD-2A with a d-c voltage of 28 v. Potentiometer R8-41 (VRD), located on the front panel of the unit, sets the output voltage of the rectifier.

49. Construction of the Comparator

The comparator unit is built in a box chassis, one wall of which

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forms the front panel. All parts are mounted on plates to provide free access to the parts when replacement may be necessary (fig. 107, 108).

The housing is fastened to the chassis with screws.

On the front panel of the unit are the following:

1) "Range Zero" potentiometer (R-24).

2) "Range Scale" potentiometer (R-16).

3) "Pull-Out" potentiometer (R-12).

4) "VRD Calibration" potentiometer (R-41).

5) six control points.

6) Two terminals: "Out. D" and "Out. VRD", which can be used to check the comparator and pull-out channels in the aircraft or in the absence of VRD-2A.

The unit is connected to the intermediate cable of the radar with the aid of a cable (attached to the comparator) terminated by a 32-contact plug type 2RM.

SPN
246

XI. Control Instrument (KPK)

50. Function

The control instrument KPK is designed for measuring the basic parameters of the radar, controlling its circuits, checking range calibration, accurately measuring the range voltages in both modes by the compensation method, as well as for measuring pull-out range and and errors in the comparator circuit in unit K-8.

51. Technical Data

1. Voltage control:

a.	115 v, 400 cps	(scale 300 v)
b.	+ 27 v	(scale 30 v)
c.	+ 300 v	(scale 300 v)
d.	+ 200 v	(scale 300 v)
e.	+ 150 v	(scale 300 v)
f.	- 150 v	(scale 300 v)

Measurement accuracy for all scales is no less than ± 2.5%.

2. Current control:

a.	Receiver crystal current	(scale 3 ma)
b.	AFC crystal current	(scale 3 ma)
c.	Magnetron current	(scale 3 ma)
d.	Ferrite switch current	(scale 60 ma)

Measurement accuracy for all scales is no less than ± 2.5%.

SPN
247

The Control Instrument Provides for:

a. Manual gain control (MGC) within limits of not less than 0 ÷ - 12 v in the "MGC" position of toggle-switch "AGC-MGC".

b. Manual frequency control (MFC) by changing the voltage in the reflex klystron within limits of not more than - 80 v and not less than - 120 v in the "MFC" position of toggle-switch "MFC-AFC".

The Control Instrument Calibrates the Following Voltages by the Compensation Method:

a. Range voltage in mode "A" at the points: 500 m, 1,000 m, 1,500 m, 2,000 m, 2,500 m, and 3,000 m.

b. Range voltages in mode "B" at the points: 500 m, 1,000 m, 1,500 m, 2,000 m, 2,500 m, 3,000 m, 3,500 m, 4,000 m, 4,500 m, 5,000 m, and 5,500 m.

Measurement accuracy is not less than ± 1 m.

52. Components of the Instrument

The following components are included in KPK:

a. The KPK instrument proper (GN2.761.057.)

b. Ultrasonic calibrator UKKM-1.

c. Two connecting wires with plugs.

d. Coaxial T-junction for connecting UKKM-1.

53. Description of the Operation of KPK According to Schematic Diagram (Fig. 109)

The control instrument KPK consists of two basic assemblies:

a. The control board, similar to RB6-PK.

b. The compensation measuring assembly.

SPN 248

Description of Schematic Diagram of Control Board

The following set parameters may be checked with the aid of the

control board:

a.	Voltage	115 v, 400 cps
b.	"	+ 27 v
c.	"	+ 300 v
d.	"	+ 200 v
e.	"	+ 150 v
f.	"	- 150 v
g.	TK I	crystal current of receiver channel
h.	TK II	crystal current of AFC channel
i.	T.M.	magnetron current
j.	U_d	voltage proportional to range
k.	F.K.	currents of ferrite switch

In addition, the control board provides for manual control of gain (MGC) and manual regulation of voltage at the klystron repeller in the AFC channel.

The control board circuit consists of two functional assemblies:

The assembly for measuring the parameters of the set, which includes the wafer switch "Mode" (V1-11P2N) and instrument IP-1 "Mode" of the VA-46 type.

The assembly which provides for control of the set and consists of two toggle-switches "AFC-MFC" and "AGC-MGC" and two dividers, which include the "Tuning" and "Gain" potentiometers.

The parameters of the set are checked in the following manner:

SPN 249

a) In checking the ~ 115 v, the voltage passes from two contacts Sh-1 of KPK through resistors R3; R4* and crystal diode D-1, undergoing half-wave rectification, to wafer switch V-1 (a) in position "~ 115 v" and thence through instrument IP-1 "Mode" to V-1 (b). From wafer switch V-1 (b) the "~ 115 v" voltage is applied to contact 3 of Sh-1 of KPK. Resistors R3 and R4* are selected so that the full scale

equals 300 v.

b) The "+ 27 v" voltage is fed from contact 5Sh-1 to wafer switch V-1 (a) in the position "+ 27 v" and through instrument IP-1 to V-1 (b); from the wafer switch, the "+ 27 v" measuring circuit is connected to ground through resistors R14 and R15*. Resistors R14 and R15* are selected so that the full scale of the instrument is 30 v.

v) "+ 300 v" is fed from contact 16 of connector Sh-1 to wafer switch V-1 (a) in the position "+ 300 v" and through instrument IP-1 to V-1 (b).

From the wafer switch, the "+ 300 v" measuring circuit is connected to ground through resistors R9*, R10, and R11. These resistors are selected so that the full scale equals 300 v.

g) "+ 200 v" is fed from contact 15 of connector Sh-1 to wafer switch V-1 (a) in position "+ 200 v" and through instrument IP-1 to V-1 (b); the "+ 200 v" measuring circuit is connected to ground from V-1 (b) through R9*, R10, and R11. (300 v scale).

SPN 250

d) "150 v" is fed from contact "11" of connector Sh-1 to wafer switch V-1 (a) in position "150" and through instrument IP-1 to V-1 (b). The "+ 150 v" measuring circuit is connected to ground from V-1 (b) through R9*, R10, and R11. (+ 300 v scale).

ye) "- 150 v" is fed from contact "13" of connector Sh-1 to wafer switch V-1 (b) in position "- 150 v" and through instrument IP-1 to V-1 (a). From V-1 (a), the "- 150 v" measuring circuit is connected to ground through R9*, R10, and R11. (- 300 v scale).

zh) "TK I" is fed from contact "8" of Sh-1 to wafer switch V-1 (a) in position "TK I" and through instrument IP-1 to V-1 (b). From V-1 (b), the TK I measuring circuit is connected to ground through resistor R-12*. This resistor is selected so that the full scale of the instrument equals 3 ma.

z) "TK II" is fed from contact "9" of Sh-1 to wafer switch V-1 (a) in position "TK II" and through instrument IP-1 to V-1 (b). From V-1 (b), the TK II measuring circuit is connected to ground through resistor R-12*. (3 ma scale).

i) "T.M." is fed from contact "10" of Sh-1 through resistors R-1, R-2* to wafer switch V-1 (a) in position "T.M." and through instrument IP-1 to V-1 (b). The T.M. measuring circuit is connected to ground from V-1 (b)

SPN 251

Resistors R-1 and R-2* are selected so that the full scale equals 3 ma.

k) "Uд" passes from contact "7" of connector Sh-1 to wafer switch V-1 (b) in position "Uд" and through instrument IP-1 to V-1 (a). From V-1 (a), "Uд" is fed through R5 to point + 195 v of divider R8, R6*, and R7.

With a range voltage equal to + 195 v (range equal to zero), the pointer of instrument IP-1 remains at zero. At other ranges, the instrument measures the range voltage in volts (150 v scale).

l) "F.K." passes from contact "6" of connector Sh-1 through resistors R22* and R21 to wafer switch V-1 (b) and through instrument IP-1 to V-1 (a). The current measuring circuit of the ferrite switch is connected from V-1 (a) to + 27 v. Resistors R22* and R21 are selected so that the full scale equals 60 ma.

Manual Gain Control and Manual Frequency Control

Manual gain control (MGC) and manual frequency control (MFC) are accomplished in the following manner:

Dividers R16*, R17, R18, and R19* are fed by - 150 v through toggle-switches V1 and V2. The dividers are designed so that a voltage regulated from - 30 to - 120 v is taken from potentiometer R17 (MFC) and a voltage regulated from 0 to - 12 v is taken from potentiometer R20 (MGC).

SPN 252

DESCRIPTION OF THE SCHEMATIC DIAGRAM OF THE COMPENSATION-MEASURING ASSEMBLY

The circuit of the compensation-measuring assembly consists of four functional elements:

a) Voltage dividers R-38 ÷ R47, from which a voltage proportional to the range is taken after each 500 m according to the law:

$$U_d = 195 - \frac{D_m}{20} \text{ in V.}$$

b) Voltage divider R23 ÷ R37, from which a voltage proportional to the range is taken after 500 m according to the law:

$$U_d = 195 - \frac{D_m}{50}$$

v) Voltage dividers R35, R 46, from which a voltage proportional to the range is taken after 500 m according to the law:

$$U_{d\text{-}raz\,(difference)} = 3{,}62\,D \text{ in Km}$$

g) A compensation circuit, which consists of:

a. two type VA-46 "compensation" and "error" instruments.

b. switches "+," "-," "On-Off," "Coarse-Fine."

v. Resistors R-61, R-62, R-63, R-66, R-67, R-68.

g. "Error" potentiometer (R-64).

d. Voltage rectifier circuit for supplying the "Error" potentiometer.

SPN 253

RANGE-MEASURING CIRCUIT IN MODE "A"

A voltage proportional to the range, taken by "Range" switch (V-46) from divider R38-R47 is applied through toggle switch "On-Off" (V-8), and "set mode" switch (V-5), located in position "A" on "compensation" instrument (IP-3).

"Coarse-Fine" switch (V-6) is set in the "Coarse" position.

Set voltage flows simultaneously to the instrument through the "set mode" switch in position "A" and through the "Error" instrument (IP-2). The needle of the "Error" instrument must remain at zero.

If the voltage taken from the divider is equal to the set voltage, the needle of the "compensation" instrument will also remain at zero.

If the voltages being compared are not equal, the unbalanced voltage, which is set at the "Error" potentiometer, is determined by the "Error" instrument.

Then, setting the "Coarse-Fine" switch at the "Fine" position, we determine the exact error, with the corresponding sign, directly by the "Error" instrument.

The "Error" instrument measures the difference in the compared voltages fed to it.

The entire scale is 120 meters.

SPN 254 CIRCUIT FOR MEASURING THE PULL-OUT RANGE AND ERROR OF THE COMPARITOR CIRCUIT IN UNIT "K-8"

The determine the pull-out range and error of the comparitor circuit, it is necessary to connect "Output D" and "Output VRD" in KPK with the corresponding terminals in unit "K-8."

The "calibration" toggle switch in KPK is set in the "on" position.

The "on-off" toggle switch is set in the "off" position. The "set mode" switch is set in the "O" position.

Lock on a target at a range of 1000 m, and turn on the "pull-out" light by rotating the handle of the potentiometer. Read the exact value of the pull-out range on the scale of the "Error" instrument.

$$D_{pull-out} = 1000 \text{ m} \pm D \text{ instrument.}$$

The full scale of the instrument is 150 meters.

Having set the "set mode" switch at "C" position, determine the error of the comparator circuit in an analogous manner according to whether the "Launch" light is lit upon locking on a target at distances of 1,000, 2,000, 3,000, 4,000, and 5,000 m.

In this case, the full scale of the instrument is 120 meter.

In both the above-described measurements, the "Error" instrument is connected in series with the present-range voltage circuit.

SPN 255 For fine adjustment of the VRD divider under factory conditions, the "set mode" switch has the technological position "N" (adjustment).

COMPENSATION CIRCUIT

The compensation, currentless method of measuring is used in this circuit.

It consists of the following:

A "Compensation" instrument is acted upon by two voltages: on the one hand, the voltage taken from the divider, and on the other, the set voltage.

If these voltages are equal, it means that no current flows through the instrument, and its needle stays at zero.

If the needle of the instrument is deflected to one side or the other, it means that the voltages being compared are not equal. Then, setting the "Coarse-Fine" switch in the "Fine" position, we switch in the error-measuring circuit.

In this case, "Error" potentiometer (R64), which is supplied by a rectified voltage of 3.5 v, is connected between the instrument and the voltage taken from the set.

If the voltage flowing from the set is less than the voltage taken from the divider, then the switch with the "error" sign must be set in the "+" position. Then the voltage taken from the potentiometer will be added to the voltage taken from the

set; the voltages flowing to the instrument are equalized by changing the voltage at the potentiometer.

SPN 256 The voltage at the potentiometer is measured by the "Error" instrument, which is connected to the output of the "Error" potentiometer.

For convenience in reading errors, the scale of the "Error" instrument is graduated in such a manner that the full scale corresponds to 30 m in mode "A," to 120 m in mode "B" and "C," and to 150 m, in mode "C."

54. CONSTRUCTION OF THE INSTRUMENT (Fig. 110, 111)

The control instrument is made in the form of a table model [all control located on top].

All the elements of the circuit are located on a chassis, which also forms the front panel of the instrument.

The instrument has a removable housing with a lid; the lid is fastened to the housing by two "phonograph" type locks.

There is a handle on the side of the housing for convenience in carrying.

There is a section in the housing for:

a) Ultrasonic line UKKM-1, which is fastened to the housing by two screws;

b) a coaxial T-joint;

v) two leads with plugs;

g) A KPK instrument cable;

The face panel is attached to the housing by four screws.

Controls are located to the left on the face panel and include:

SPN 257 a) A type VA-46 "Mode" instrument.

b) "Mode" wafer switch.

v) "Gain" control.

g) "Tuning" control.

d) "MGC-AGC" switch.

e) "AFC-MFC" switch.

A measuring attachment is located to the right on the face panel and includes:

a. A type VA-46 "Compensation" instrument.

b. A type VA-46 "Error" instrument.

v. "Range" (in meters) wafer switch.

g. "Set Mode" wafer switch.

d. "On-Off" switch.

e. "Coarse-Fine" switch.

zh. "+" "+" "–" switch.

z. "Error" control.

i. "Calibration-On" switch.

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SPN 262

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Pos. Design.	State National Standard, VTU Normal Drawing	Name and Type	Basic Data Rated	No.	Note
R2-1	U80 467 019TU	Resistance ULM-0.12-220 Ohm-I	220 Ohm	1	
R2-2	U80 467 019TU	Resistance ULM-0.12-3.3 kOhm-I	3.3 kOhm	1	
R2-3	U80 467 019TU	Resistance ULM-0.12-2.7 kOhm-I	2.7 kOhm	1	
R2-4	U80 467 019TU	Resistance ULM-0.12-3 kOhm-I	3 kOhm	1	
R2-5	U80 467 019TU	Resistance ULM-0.12-220 Ohm-I	220 Ohm	1	
R2-6	U80 467 019TU	Resistance ULM-01.12-4.7 kOhm-I	4.7 kOhm	1	
R2-	OZh0467 003TU	Resistance MLT-1.1.5 kOhm-I	1.5 kOhm	1	
R2-9	OZh0467 003TU	Resistance MLT-1-1 kOhm-I	1 kOhm	1	
R2-10	OZh0467 003TU	Resistance MLT-1-43 kOhm-II-B	43 kOhm	1	
R2-12	OZh0467 003TU	Resistance MLT-1-10 kOhm-II-B	10 kOhm	1	
R2-13	OZh0467 003TU	Resistance MLT-1-47 kOhm-II-B	47 kOhm	1	
R2-14	OZh0467 003TU	Resistance MLT-1-68 kOhm-II-B	68 kOhm	1	
R2-15	OZh0467 003TU	Resistance MLT-1-220 Ohm-II	220 Ohm	1	
R2-16	OZh0467 003TU	Resistance MLT-1-4.3 MOhm-II-B	4.3 MOhm	1	
R2-17	OZh0467 003TU	Resistance MLT-4.3 MOhm-II-B	4.3 MOhm	1	

Nomenclature of Elements

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Pos. Design.	State National Standard, VTU Normal Drawing	Nomenclature of Elements	Basic Data Rated	No	Note
R2-18	OZh0467 003TU	Resistance MLT-1-4.3-II-B	4.3 MOhm	1	
R2-19	OZh0467 003TU	Resistance MLT-1-4.3-II-B	4.3 MOhm	1	
R2-20	OZh0467 003TU	Resistance MLT-1-2-kOhm-II	2 kOhm	1	
R2-21	OZh0467 003TU	Resistance PEV-10-3-kOhm-II	3 kOhm	1	
R2-22	OZh0467 003TU	Resistance MLT-2-1MOhm-II-B	1 MOhm	1	
R2-23	OZh0467 003TU	Resistance MLT-2-1MOhm-II-B	1 MOhm	1	
R2-24	OZh0467 003TU	Resistance MLT-2-1MOhm-II-B	1 MOhm	1	
R2-26	OZh0467 003TU	Resistance MLT-2-100 Ohm	100 Ohm	1	
R2-28	OZh0467 003TU	Resistance MLT-1-1kOhm-II	1 kOhm	1	
R2-29	OZh0467 003TU	Resistance MLT-0.5-100kOhm-I	100 kOhm	1	
R2-31	OZh0467 003TU	Resistance MLT2-240kOhm-II-B	240 kOhm	1	
R2-32	OZh0467 003TU	Resistance MLT-05-2.7 kOhm-II	2.7 kOhm	1	
R2-33	OZh0467 003TU	Resistance MLT-2-12-kOhm-II-B	12 kOhm	1	
R2-34	OZh0467 003TU	Resistance MLT-0.5-100 Ohm-I	100 Ohm	1	

Nomenclature of Elements

Pos. Design	State National Standard, VTU Normal Drawing	Name and Type	Basic Data Rated	No.	Note
Rs-35	OZhO 467 003TU	Resistance MLT-2-1.2MOhm-II-B	1.2 MOhm	1	
R2-36	OZhO 467 003TU	Resistance MLT-1-4.3MOhm-II-B	4.3 MOhm	1	
R2-37	OZhO 467 003TU	Resistance MLT-1-4.3MOhm-II-B	4.3 MOhm	1	
R2-38	OZhO 467 003TU	Resistance MLT-1-100kOhm-II-B	100kOhm	1	
R2-39	OZhO 467 003TU	Resistance MLT-1-8200kOhm-II-B	820kOhm	1	
R2-40	OZhO 467 003TU	Resistance MLT-2-240kOhm-II-B	240kOhm	1	
R2-41	OZhO 467 003TU	Resistance MLT-2-220 Hom-II-B	220 Ohm	1	
R2-44	OZhO 467 003TU	Resistance MLT-1-2kOhm-II	2kOhm	1	
R2-45	OZhO 467 003TU	Resistance MLT-0.5-3.9-kOhm-II	3.9kOhm	1	
R2-46	OZhO 467 003TU	Resistance MLT-0.5-3.3-kOhm-II	3.3kOhm	1	
R2-47	OZhO 467 003TU	Resistance MLT-0.5-220-Ohm-II	220-Ohm	1	
R2-48	OZhO 467 003TU	Resistance MLT-0.5-30-kOhm-IIB	30-kOhm	1	
R2-49	OZhO 467 003TU	Resistance MLT-0.5-220-Ohm-II	220-Ohm	1	
R2-50	OZhO 467 003TU	Resistance MLT-0.5-3.3-kOhm-II	3.3-kOhm	1	
R2-51	OZhO 467 003TU	Resistance MLT-0.5-100kOhm-IIB	100-kOhm	1	
R2-52	OZhO 467 003TU	Resistance MLT-0.5-220kOhm-IIB	220 kOhm	1	
R2-53	OZhO 467 003TU	Resistance MLT-0.5-1MOhm-II-B	1MOhm	1	

S-E-C-R-E-T

Nomenclature of Elements

pos. desig.	State National Standard, VTU Normal Drawing	Name and Type	Basic Data Rated	No	Note	change
R2-54	OZhO 467 003TU	Resistance MLT-0.5-1.5-kOhm-II	1.5 kOhm	1		
R2-55	OZhO 467 003TU	Resistance MLT-0.5-2.4-kOhm-II	2.4 kOhm	1		
R2-56	OZhO 467 003TU	Resistance MLT-0.5-2.2-kOhm-II	2.2 kOhm	1		
R2-57	OZhO 467 003TU	Resistance MLT-0.5-12-kOhm-II-B	12 kOhm	1		
R2-58	OZhO 467 003TU	Resistance MLT-0.5-12-kOhm-II-B	12 kOhm	1		
R2-59	OZhO 467 003TU	Resistance MLT-0.5-100-kOhm-II-B	100 kOhm	1		
R2-60	OZhO 467 003TU	Resistance MLT-0.5-100-kOhm-II-B	100 kOhm	1		
R2-61	OZhO 467 003TU	Resistance MLT-0.5-100-kOhm-II-B	100 kOhm	1		
R2-62	OZhO 467 003TU	Resistance MLT-0.5-15-kOhm-II-B	15 kOhm	1		
R2-63	OZhO 467 003TU	Resistance MLT-0.5-15-kOhm-II-B	15 kOhm	1		
R2-64	OZhO 467 003TU	Resistance MLT-0.5-470-kOhm-II-B	470 kOhm	1		
R2-65	OZhO 467 003TU	Resistance MLT-0.5-12-kOhm-II-B	12 kOhm	1		
R2-66	OZhO 467 003TU	Resistance MLT-0.5-39-kOhm-II-B	39 kOhm	1		
R2-67	OZhO 467 003TU	Resistance MLT-0.5-100-kOhm-II-B	100 kOhm	1		
R2-68	OZhO 467 003TU	Resistance MLT-0.5-100-kOhm-II-B	100 kOhm	1		

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Nomenclature of Elements

pos. desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Date Rated	No.	No.	chan.
R2-69	0Zh0 467 003TU	Resistance MLT-0.5-100-kOhm-II-B	100 kOhm	1		
R2-70	0Zh0 467 003TU	Resistance MLT-0.5-24-kOhm-II-B	24 kOhm	1		
R2-71	474 685 057	Resistance ILZ-43-20-kOhm-II	20 kOhm	1		
R2-72	0Zh0 467 003TU	Resistance MLT-0.5-36-kOhm-II-B	36 kOhm	1		
R2-73	0Zh0 467 003TU	Resistance MLT-0.5-33-kOhm-I -B	33 kOhm	1		
R2-74	0Zh0 467 003TU	Resistance MLT-0.5220-kOhm-I	220 kOhm	1		
R2-75	0Zh0 467 003TU	Resistance MLT-0.5-470-kOhm-I-B	470 kOhm	1		
R2-76	0Zh0 467 003TU	Resistance MLT-0.5-3-kOhm-II	3 kOhm	1		
R2-77	0Zh0 467 003TU	Resistance MLT-0.5-560-kOhm-I	560 kOhm	1		
R2-78	0Zh0 468 004TU	Resistance SL-II-2a-330-kOhm-II	330 kOhm	1		
C2-1	UBO 460 015 TU	Capaditor-KO-1-SK-1000	1000 pf	1		
C2-2	UBO 460 002 TU	Capacitor KD3-10-1000	1000 pf	1		
C2-3	UBO 460 002 TU	Capacitor KD3-10-1000	1000 pf	1		
C2-4	UBO 460 002 TU	Capacitor KD3-1a-1000	1000 pf	1		

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Nomenclature of Elements

pos. desig.	State National Standard, VTU Normal Drawing	Name and Type	Basic Data rated	No.	Note chan.
C2-5	UBO 460 047TU	Capacitor KTK-a-N-33±10%-35	33 pf	1	
C2-6	UBO 460 00 TU	Capacitor KDS-1a-1000	1000 pf	1	
C2-7	UBO 460 002TU	Capacitor KDS-1a-1000	1000 pf	1	
C2-9	UBO 460 015TU	Capacitor KO-1-M-1000	1000 pf	1	
C2-10	UBO 460 015TU	Capacitor KO-1-N-1000	1000 pf	1	
C2-11	UBO 460 015TU	Capacitor KO-1-N-1000	1000 pf	1	
C2-12	UBO 460 041TU	Capacitor KTK-0-D-100 ±10% -35	100 pf	1	
C2-13	OZhO 452 011TU	Capacitor BGM-2-400-0.05-II	0.05 pf	1	
C2-14	OZhO 452 011TU	Capacitor BGM-2-400-0.01-II	0.01 pf	1	
C2-15	OZhO 462 022-TU	Capacitor MBGP-2-400-2-al-II	2-al	1	together with C2-20
C2-16	OZhO 461 015TU	Capacitor KSO-8-2500-6-2000-II	2000 pf	1	
C2-17	OZhO 462 011TU	Capacitor BGM-2-400-0.01-II	0.01µf	1	
C2-18a	OZhO 462 009TU	Capacitor MBGT-1000-0.5-II	0.5µf	1	
C2-19	OZhO 462 022TU	Capacitor MBGP-2-400-2-0.1-II	2-0.1	1	together with C2-26

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Nomenclature of Elements

pos. desig.	State National Standard, VTU Normal Drawing	Name and Type	Basic data rated	No.	note	chan.
C2-20	OZhO 462 022TU	Capacitor MBGP-2-400-2-0.1-II	2-0.1	1	together with C2-19	
C2-21	OZhO 462 011TU	Capacitor BGM-1-400-0.05-II	0.05 µf	1		
C2-22	OZhO 462 011TU	Capacitor BGM-1-400-0.05-II	0.05 µf	1		
C2-23	OZhO 462 011TU	Capacitor BGM-1-400-0.05-II	0.05 µf	1		
C2-24	OZhO 462 001TU	Capacitor BGM-1-400-0.05-II	0.05 µf	1		
C2-25	OZhO 462 002TU	Capacitor KDS-1a-1000-II	1000 pf	1		
C2-26	OZhO 462 022TU	Capacitor MBGP-2-400-2-0.25-II	2-025	1	together with C2-19	
C2-27	UBO 460 015TU	Capacitor KO-1-N-1000	1000 pf	1		
C2-28	UBO 460 015TU	Capacitor KO-10-1000	1000 pf	1		
C2-29	OZhO 452 011TU	Capacitor BGM-1-400-920-II	920 pf	1		
C2-30	UBO 460 002TU	Capacitor KDS-10-1000-II	1000 pf	1		
C2-31	UBO 462 009TU	Capacitor MBGT-1000-0.25-II	0.25 µf	1		
C2-18	UBO 462 009TU	Capacitor MBGT-1000-0.5-II	0.5 µf	1		

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Nomenclature of Elements

pos. design	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	ch.
C2-34	OZhO 462 011TU	Capacitor BGM-2-400-0.01-II	0.01 μf	1		
C2-35	UBO 460 029TU	Capacitor KO-1-M-1000-II	1000 μf	1		
C2-36	OZh4 600 001TU	Capacitor KDS-1a-1000	1000 pf	1		
C2-37	OZh4 600 001TU	Capacitor KDS-1a-1000	1000 pf	1		
C2-38	OZh4 600 001TU	Capacitor KDS-1a-1000	1000 pf	1		
C2-39	OZh4 600 001TU	Capacitor KDS-1a-1000	1000 pf	1		
C2-40	UBO 460 029TU	Capacitor KO-1-N-1000-II	1000 pf	1		
C2-41	OZhO 462011TU	Capacitor BGM-1-400-0.01-II	0.01 μf	1		
C2-42	UBO 460 029TU	Capacitor KD-1-N-1000-II	1000 pf	1		
C2-43	OZh4 600 001TU	Capacitor KDS-1a-1000	1000 pf	1		
C2-44	OZh4 600 001TU	Capacitor KDS-1a-1000	1000 pf	1		
C2-45	OZh4 600 001TU	Capacitor KDS-1a-1000	1000 pf	1		
C2-46	UBO 460 041TU	Capacitor KTK-A-M-12±10% -3β	12 pf	1		
C2-47	UBO 460 041TU	Capacitor KTK-A-M-3.9±10% -3β	3.9 pf	1		
C2-48	OZhO 462 011TU	Capacitor BGM-1-400-0.01-II	0.01 μf	1		

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Nomenclature of Elements

pos. design.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Da Data Rated	No.	Note	ch.
C2-49	UBO 460 041TU	Capacitor KTK-A-M-47±10% -3B	47 pf	1		
C2-50	UBO 460 041TU	Capacitor KTK-A-M-47±10% -3B	47 pf	1		
C2-51	OZhO 462 011TU	Capacitor BGM-2-400-0.01-II	0.01 μf	1		
C2-52	OZhO 462 011TU	Capacitor BGM-1-400-0.01-II	0.01 μf	1		
C2-53	OZhO 462 011TU	Capacitor BGM-2-400-0.01-II	0.01 μf	1		
C2-54	UBO 460 041TU	Capacitor KTK-A-M-10±10% -3B	10 pf	1		
C2-55	OZhO 462 011TU	Capacitor BGM-2-400-0.01-II	0.01 μf	1		
C2-56	OZhO 462 011TU	Capacitor BGM-2-400-0.01-II	0.01 μf	1		
C2-57	OZhO 462 022TU	Capacitor MBT-1-200-2.05-II	2.05 μf	1		
C2-58	UBO 460 041TU	Capacitor KTK-A-M-27±10% -3B	27 pf	1		
C2-59	UBO 460 002TU	Capacitor KDS-1a-1000-III	1000 pf	1		
C2-60	UBO 460 002TU	Capacitor KDS-1a-1000-III	1000 pf	1		
C2-61	UBO 460 002TU	Capacitor KDS-1a-1000-III	1000 pf	1		
C2-62	UBO 460 002TU	Capacitor KDS-1a-1000-III	1000 pf	1		
C2-63	UBO 460 002TU	Capacitor KDS-3a-6800-III	6800 pf	1		

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Nomenclature of Elements

pos. desi.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	ch.
C2-64	UBO 464 005TU	Capacitor KS-500-0-150-II	150 pf	1		
C2-65	UBO 460 002TU	Capacitor KDS-1a-1000-II	1000 pf	1		
C2-66	UBO 460 002TU	Capacitor KDS-1a-1000-II	1000 pf	1		
L2-1	GYaCh 775·002SP	Coil, Induction	2.8 μh	1		
C2-70	OZhO 460 011TU	Capacitor BGM-1-400-0.05-II	0.05 μf	1		
L2-3	GUCh 777 004SP	Choke, Coil filament, D-2.4-5±10%	5 μh	1		
L2-4	GUCh 777 003SP	Choke, RF-D-0.15-20μh	20 μh	1		
L2-5	GUCh 777 004SP	Choke, Coil filament, D-2.4-5±10%	5 μh	1		
L2-6	GYaCh 777 011SP	Coil, Induction, 2.5 μh±5%	2.5 μh	1		
L2-7	GYaCh 777 013SP	Coil, Induction, 4.1 μh±0.1 μh	4.1 μh	1		
L2-8	AR-50-2-5-1-000	Coil, Induction, 5 μh	5 μh	1		
L2-9	AR-1-1-2-D-OB24	Coil, Induction, 75 μh	75 μh	1		
L2-10	GUCh 777 004SP	Choke D-0.1-450 μh ±5%	450 μh	1		
L2-11	GUCh 777 004SP	Choke D-0.4-5 μh±5%	5 μh	1		
L2-12	GUCh 777 004SP	Choke D-0.15-5.1 μh±5%	5 μh	1		

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Nomenclature of Elements

Pos. desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note
L2-13	GUCh 777 004SP	Choke D-0.15-5.1 μh±5 %	5.1 μh	1	
L2-14	GUCh 777 004SP	Choke D-0.15-5.1 μh±5%	5.1 μh	1	
L2-15	GUCh 777 004SP	Choke D-0.15-5.1 μh ±5%	5.1μh	1	
L2-16	GUCh 777 004SP	Choke D-0.15-5.1 μh ±5%	5.1 μh	1	
L2-17	GUCh 777 004SP	Choke D-0.15-5.1μh ±5%	5.1 μh	1	
L2-18	GUCh 777 003SP	Choke, Filament-1.2-5±10%	5 μh	1	
L2-19	AR50-2-52-000	Choke, Filament-0.6 μh	0.6 μh	1	
L2-20	GYaCh 777 010SP	Coil, Induction-1.6 μh	1.6 μh	1	
L2-21	GYaCh 777 009SP	Coil, Induct.-2.8 μh	2.8 μh	1	
L2-22	GUCh 777 003SP	Choke, RF-D-0.15-20 μh	20 μh	1	
L2-23	GYaCh 775 002SP	Coil, Induct.	2.8 μh	1	
Dr2-1	AR50-2-61-000	Choke, Charging		1	
L2-25	GUCh 777 004SP	Choke D-0.15-39 μh±5%	39 μh	1	
Tr2-1	GYaCh 770 004SP	Transformer, RF		1	
Tr2-2	GYaCh 770 035SP	Transformer, RF		1	

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Nomenclature of Elements

pos. desig	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note
Tr2-3	GYaCh 720 005SP	Transformer, Impulse		1	
Tr2-4	GYaCh 712 003SP	Transformer, RF		1	
Tr2-5	GYaCh 720 026SP	Transformer, Impulse		1	
Tr2-6	GYaCh 710 068SP	Transformer, Filament		1	
Tr2-7	GYaCh 710 004SP	Transformer, RF		1	
Tr2-8	GYaCh 770 013SP	Transformer, RF		1	
Tr2-9	TU-9575	Transformer	1.95/2.5μh	1	
Tr2-10	GYaCh 714 036SP	Transformer, Anode Filament		1	
C2-67	OZhO 46-10-15TU	Capacitor KSO-8-2000-B-4300-I	4300 pf	1	
C2-68	OZhO 46-10-15TU	Capacitor KSO-8-2000-B-4300-I	4300 pf	1	
C2-69	OZhO 46-10-45TU	Capacitor KSO-8-2000-B-4300-I	4300 pf	1	
C2-78	OZhO 46-10-15TU	Capacitor KSO-8-2000-B-4300-I	4300 pf	1	
LF2-1	AR50-2-59-000	Pulse Shaping Line		1	
LF2-1	GYa38-61-004SP	Heater of Discharging tube		1	
LF2-1	1RM2-21-000	Thermostat		1	

SECRET

Nomenclature of Elements

pos. desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	ch.
LF2-1		Electric Motor D-5		1		
		OKB p/Ya 174				
L2-1	ChTU 01-318-56	Tube 6Zh1B		1		
L2-2	ChTU 01-318-56	Tube 6Zh1B		1		
L2-3	ChTU 01-105-55	Tube 6N1P		1		
L2-4	TS3-301-000TU	Tube 6N3P		1		
L2-5	TS3-341-000TU	Gas Rectifier TKh-2		1		
L2-6	TS3-341-000TU	Gas Rectifier TKh-2		1		
L2-7	ChTU-10-311-56	Thyrotron TGI-1-35/3		1		
L2-8	T3-174-50S	Spark Discharger R-1		1		
L2-9	VChTU06-609-51	Magnetron MI-158		1		
L2-10	TS3-341-000TU	Gas Rectifier TKh-2		1		
L2-11	YaI0332-032TU	Clystron K-27		1		
L2-12	YaI0332 002TU-5	Discharger R-21		1		

Nomenclature of Elements

pos. des.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	Ch.
L2-13	ChTU-12-102-53	Discharger RA-50		1		
L2-15	ChTU02-300-57	Tube SG-5B		1		
L2-16	01317-57TU	Tube 6S 7B		1		
L2-17	ChTU-01-103-55	Tube 6Zh 1P		1		
L2-18	ChTU-01-103-55	Tube 6Zh1P		1		
L2-19	ChTU-01-108-55	Tube 6Kh2P		1		
L2-20	TS3-301-000TU	Tube 6N3P		1		
L2-21	ChTU-01-105-55	Tube 6N2P		1		
F2-1	GUZ 540 010SP	Plug-and-Socket, RF, VR-10		1		
F2-2	GYaZ 540 018	Plug-and-Socket Transition		1		
F2-3	GUZ 540 008SP	Plug-and-Socket, RF		1		
F2-4	GUZ 540 008SP	Plug-and-Socket, RF		1		
F2-5	GUZ 540 010SP	Plug-and-Socket, RF, VR-8		1		
F2-6	GUZ 540 010SP	Plug-and-Socket, RF, VR-8		1		

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pos. des.	State National Standard, VTU, Normal Drawing	Nomenclature of Elements: Name and Type	Basic Data Rated	No.	Ch.
F2-7	GYaZ 540 020	Plug-and-Socket, RF,		1	
KT2-1	TU- 11161	Control Point		1	
KT2-2	TU-111 61	Control Point		1	
KT2-3	TU-1 11 61	Control Point		1	
Sh2-1	AR18-2-7sb05	Plug, 5-Pin Plug		1	
Sh2-2	AR18-2-7sb03	Receptacle, 5-Jack Receptacle		1	
Sh2-3	VLO-364-006TU	Plug RGChOP17NSh1		1	
Sh2-4	GYaZ 695 001SP	Plug 11-Pins Plug		1	
Sh2-5	GYaZ 695 001SP	Receptacle, 11-Jack Receptacle		1	
V2-1	VRZ-602-001SP	Switch		1	
D2-1	ChTU-04-110-57	Crystal Detector DGS-M		1	
D2-2	ChTU-04-110-57	Crystal Detector DGS-N		1	
D2-3	ChTU-04-110-57	Crystal Detector DGS-V		1	
D2-4	ChTU-04-110-57	Crystal Detector DGS-V		1	

List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note.	Ch.
1	2	3	4	5	6	
R-3-1	0Zh0-467-003TU	Resistor, MLT-0.5-150 Ohm-I	150 Ohm	1		
R-3-2	0Zh0-467-003TU	Resistor, MLT-0.5-150 Ohm-I	150 Ohm	1		
R-3-3	0Zh0-467-003TU	Resistor, MLT-0.5-220 Ohm-I	220 Ohm	1		
R-3-4	0Zh0-467-003TU	Resistor, MLT-0.5-3.9kOhm-I	3.9kOhm	1		
R-3-5	0Zh0-467-003TU	Resistor, MLT-0.5-3.3kOhm-I	3.3kOhm	1		
R-3-6	0Zh0-467-003TU	Resistor, MLT-0.5-220 Ohm-I	220 Ohm	1		
R-3-7	0Zh0-467-003TU	Resistor, MLT-0.5-5.1kOhm-I	5.1kOhm	1		
R-3-8	0Zh0-467-003TU	Resistor, MLT-0.5-3.9kOhm-I	3.9kOhm	1		
R-3-9	0Zh0-467-003TU	Resistor, MLT-0.5-10 kOhm-I	10 kOhm	1		
R-3-10	0Zh0-467-003TU	Resistor, MLT-0.5-220 Ohm-I	220 Ohm	1		
R-3-12	0Zh0-467-003TU	Resistor, MLT-0.5-5.1kOhm-I	5.1kOhm	1		
R-3-13	0Zh0-467-003TU	Resistor, MLT-0.5-10 kOhm-I	10 kOhm	1		
R-3-14	0Zh0-467-003TU	Resistor, MLT-0.5-3.9kOhm-I	3.0kOhm	1		
R-3-15	0Zh0-467-003TU	Resistor, MLT-0.5-220 Ohm-I	220 Ohm	1		

List of Elements

POS. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	Ch.
R-3-17	0Zh0-467-003TU	Resistor, MLT-0.5-3.9kOhm-I	3.9kOhm	1		
R-3-18	0Zh0-467-003TU	Resistor, MLT-0.5-5.1kOhm-I	5.1kOhm	1		
R-3-19	0Zh0-467-003TU	Resistor, MLT-0.5-220 Ohm-I	220 Ohm	1		
R-3-20	0Zh0-467-003TU	Resistor, MLT-0.5-5.1kOhm-I	5.1kOhm	1		
R-3-22	0Zh0-467-003TU	Resistor, MLT-0.5-12kOhm-I	12 kOhm	1		
R-3-23	0Zh0-467-003TU	Resistor, MLT-1-9.1 kOhm-I	9.1kOhm	1		
R-3-25	0Zh0-467-003TU	Resistor, MLT-0.5-3.3kOhm-I	3.3kOhm	1		
R-3-26	0Zh0-467-003TU	Resistor, MLT-0.5-22kOhm-I	22 kOhm	1		
R-3-27	0Zh0-467-003TU	Resistor, MLT-0.5-680 Ohm-I	680 Ohm	1		
R-3-28	0Zh0-467-003TU	Resistor, MLT-1-1.6 Ohm-I	1.6 Ohm	1		
R-3-29	0Zh0-467-003TU	Resistor, MLT-0.5-430kOhm-I	430kOhm	1		
R-3-30	0Zh0-467-003TU	Resistor, MLT-2-220 Ohm-I	220 Ohm	1		
R-3-31	0Zh0-467-003TU	Resistor, MLT-0.5-680 Ohm-I	680 Ohm	1		
R-3-33	0Zh0-467-003TU	Resistor, MLT-0.5-220 Ohm-I	220 Ohm	1		
R-3-34	0Zh0-467-003TU	Resistor, MLT-1-2MOhm-II	2MOhm	1		

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List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	Ch.
R-3-35	OZhO-467-003TU	Resistor, MLT-1-10kOhm-II	10kOhm	1		
R-3-36	OZhO-467-003TU	Resistor, MLT-1-62kOhm-I	62kOhm	1		
R-3-37	OZhO-467-003TU	Resistor, MLT-1-33kOhm-II	33kOhm	1		
R-3-38	OZhO-467-003TU	Resistor, MLT-1-15 MOhm-II	15 MOhm	1		
R-3-39	OZhO-467-003TU	Resistor, MLT-1-5.1MOhm-II	5.1MOhm	1		
R-3-40	OZhO-467-003TU	Resistor, MLT-1-12MOhm-II	12MOhm	1		
R-3-41	OZhO-467-003TU	Resistor, MLT-1-910kOhm-II	910kOhm	1		
R-3-42	OZhO-467-003TU	Resistor, MLT-1-20kOhm-II	20kOhm	1		
R-3-43	OZhO-467-003TU	Resistor, MLT-1-100kOhm-II	100kOhm	1		
R-3-44	OZhO-467-003TU	Resistor, MLT-1-62kOhm-II	62kOhm	1		
R-3-45	OZhO-467-003TU	Resistor, MLT-11-6.8kOhm-II	6.8kOhm	1		
R-3-46	OZhO-467-003TU	Resistor, MLT-1-430 Ohm-II	430 Ohm	1		
R-3-47	OZhO-467-003TU	Resistor, MLT-1-510kOhm-II	510kOhm	1		
R-3-48	OZhO-467-003TU	Resistor, MLT-1-330kOhm-II	330kOhm	1		
R-3-49	OZhO-467-003TU	Resistor, MLT-1-200kOhm-II	200kOhm	1		

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List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note, Ch.
R-3-50	OZhO-467-003TU	Resistor, MLT-1-68kOhm-I	68kOhm	1	
R-3-51	OZhO-467-003TU	Resistor, MLT-1-680kOhm-I	680kOhm	1	
R-3-52	OZhO-467-003TU	Resistor, MLT-1-330kOhm-II	330kOhm	1	
R-3-53	OZhO-468-003TU	Resistor, SN-1-2a-1.2A-13	1.2kOhm	1	
R-3-54	OZhO-467-003TU	Resistor, MLT-0.5-1.5kOhm-I	1.5kOhm	1	
R-3-55	OZhO-467-003TU	Resistor, MLT-1-470-kOhm-II	470kOhm	1	
R-3-56	VP4-675-004SN	Resistor, PT-0.5-8.2 kOhm±1%	8.2kOhm	1	
R-3-57	VP4-675-004SN	Resistor, PT-0.5-3.3 kOhm±1%	3.3kOhm	1	
R-3-58	VP4-675-004SN	Resistor, PT-0.5-2 kOhm±1%	2kOhm	1	
R-3-59	VP4-675-004SN	Resistor, PT-0.5-1 kOhm±1%	1kOhm	1	
R-3-60	NGKh4-685-018SP	Resistor, PP3-II-20kOhm-II	20kOhm	1	
R-3-65	NGKh4-685-018SN	Resistor, PP3-II-10-kOhm-I	10kOhm	1	
R-3-66	VP4-675-004SP	Resistor, PT-0.5-6.8kOhm±1%	6.8kOhm	1	
R-3-67	OZhO-467-003TU	Resistor, MLT-1-15 kOhm-I	15 kOhm	1	
R-3-68	OZhO-467-003TU	Resistor, MLT-1-2.4 kOhm-II	2.4 kOhm	1	

List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	Ch.
R-3-69	OZhO-467-003TU	Resistor, MLT-2-4.3 kOhm-1	4.3 kOhm	1		
R-3-70	OZhO-467-003TU	Resistor, MLT-1-560 kOhm-I	560 kOhm	1		
R-3-72	GYa4-675-009	Resistor, PT-I-P-82 kOhm±0.5%	82 kOhm	1		
R-3-73	GYa4-675-009	Resistor, PT-IM-82 kOhm±0.5%	82 kOhm	1		
R-3-74	OZhO-487-003TU	Resistor, MLT-T-680 kOhm-II	680 kOhm	1		
R-3-75	VP4-675-004SP	" MLT--1-30 kOhm±1%	30 kOhm	1		
R-3-76	OZhO-467-003TU	" MLT-I-10 kOhm-II	10 kOhm	1		
R-3-77	"	" MLT-1-24 kOhm-II	24 kOhm	1		
R-3-78	"	" MLT-I-10 kOhm-II	10 kOhm	1		
R-3-79	"	" MLT-I-2.4 kOhm-II	2.4 kOhm	1		
R-3-80	"	" MLT-I-39 kOhm -II	39 kOhm	1		
R-3-81	"	" MLT-I-100 kOhm-II	100 kOhm	1		
R-3-82	"	" MLT-I-100 kOhm-II	100 kOhm	1		
R-3-83	"	" MLT-I-68 kOhm-II	68 kOhm	1		
R-3-85	"	" MLT-I-100 kOhm-II	100 kOhm	1		

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Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note Ch.
R-3-86	OZhO-467-003TU	Resistor, MLT-I-100 kOhm-II	100 kOhm	1	
R-3-87	"	" MLT-I-68 kOhm-II	68 kOhm	1	
R-3-88	"	" MLT-0.5-1.2 kOhm-II	1.2kOhm	1	
R-3-89	"	" MLT-1-5.1 kOhm-II	5.1 kOhm	1	
R-3-90	"	" MLT-I-430 kOhm-II	430 kOhm	1	
R-3-91	"	" MLT-2-20 kOhm-II	20 kOhm	1	
R-3-92	"	" MLT-I-3.0 kOhm-II	3.0 kOhm	1	
R-3-93	"	" MLT-I-510 kOhm-II	510 kOhm	1	
R-3-94	"	" MLT-I-3.0 kOhm-II	3 kOhm	1	
R-3-95	"	" MLT-I-2.0 kOhm-II	2 kOhm	1	
R-3-97	"	" MLT-2-100 kOhm-II	100 kOhm	1	
R-3-98	"	" MLT-I-220 kOhm-II	220 kOhm	1	
R-3-99	"	" MLT-I-510 kOhm-II	510 kOhm	1	
R-3-100	"	" MLT-2-22 kOhm-II	22 kOhm	1	
R-3-101	"	" MLT-I-100 kOhm-II	100 kOhm	1	

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Pos. Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	Ch.
R-3-102	OZhO-467-003TU	Resistor, MLT-I-200 kOhm-II	200 kOhm	1		
R-3-103	"	" MLT-I-100 kOhm-II	100 kOhm	1		
R-3-104	"	" MLT-I-130 kOhm-II	130kOhm	1		
R-3-105	"	" MLT-I-1.0 kOhm-II	1.0 kOhm	1		
R-3-106	"	" MLT-I-820 kOhm-II	820 kOhm	1		
R-3-107	"	" MLT-I-68 kOhm-II	68 kOhm	1		
R-3-108	"	" MLT-I-100 kOhm-II	100 kOhm	1		
R-3-109	"	" MLT-I-39 kOhm-II	39 kOhm	1		
R-3-110	"	" MLT-I-510 kOhm-II	510 kOhm	1		
R-3-111	"	" MLT-0.5-12 kOhm-II	12 kOhm	1		
R-3-112	"	" MLT-I-510 kOhm-II	510 kOhm	1		
R-3-113	NGKh4-685-018SP	" PP3-II-20 kOhm-II	20 kOhm	1		
R-3-114	OZhO-467-003TU	" MLT-I-1.1 kOhm-I	1.1 kOhm	1		
R-3-115	"	" MLT-I-300 kOhm-I	300 kOhm	1		
R-3-116	"	" MLT-I-2.0 kOhm-II	2.0 kOhm	1		

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List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No	Note
R-3-118	0Zh0-467-003TU	Resistor, MLT-I-1.0 MOhm-II	1.0 MOhm	1	
R-3-119	"	Resistor, MLT-I-150 kOhm-I	150 kOhm	1	
R-3-123	"	" MLT-I-1.0 MOhm-II	1.0 MOhm	1	
R-3-124	"	" MLT-I-300 kOhm-I	300 kOhm	1	
R-3-125	"	" MLT-I-27 kOhm-I	27 kOhm	1	
R-3-126	"	" MLT-I-560 kOhm-I	560 kOhm	1	
R-3-127	"	" MLT-I-200 kOhm-I	200 kOhm	1	
R-3-128	"	" MLT-I-200 kOhm-I	200 kOhm	1	
R-3-129	"	" MLT-I-6.8 kOhm-I	6.8 kOhm	1	
R-3-131	"	" MLT-I-100 Ohm-II	100 Ohm	1	
R-3-133	"	" MLT-0.5-47 kOhm-II	47 kOhm	1	
R-3-134	"	" MLT-I-51 kOhm-II	51 kOhm	1	
R-3-137	"	" MLT-I-82 kOhm-II	82 kOhm	1	
R-3-138	"	" MLT-I-6.8 kOhm-II	6.8 kOhm	1	

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List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type		Basic Data Rated	No.	Note	Ch.
R-3-139	0Zh0-467-003TU	Resistor,	MLT-I-150 Ohm-II	150 Ohm	1		
R-3-140	"	"	MLT-I-68 kOhm-II	68 kOhm	1		
R-3-141	"	"	MLT-I-3.3 kOhm-II	3.3 kOhm	1		
R-3-142	"	"	MLT-I-510 kOhm-II	510 kOhm	1		
C3-5	TU-I-0Zh0-460-001	Capacitor	KDO-1a-1000	1000 pf	1		
C3-1	"	"	K01-N-1000-II	"	1		
C3-2	TU-I-0Zh0-460-001	"	KDS-1a-1000	"	1		
C3-3	"	"	"	"	1		
C3-4	"	"	"	"	1		
C3-7	"	"	"	"	1		
C3-6	TU-I-0Zh0-460-001	"	KO-1a-1000-II	"	1		
C3-8	"	"	KDS-1a-1000	"	1		
C3-9	"	"	"	"	1		
C3-10	"	"	KDS-1a-1000	"	1		
C3-11	"	"	"	"	1		

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List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note.	Gr.
1	2	3	4	5	6	7
C3-12	Tu-I-0Zh0-460-001	Capacitor, KDS-1a-1000	1000 pf	1		
C3-13	UB0-462-017TU	" BGI-T-1-680-V	680 pf	1		
C3-14	TU-I-0Zh0-460-00	" KDS-1a-1000	1000 pf	1		
C3-15	"	" "	"	1		
C3-16	"	" "	"	1		
C3-17	UB0-462-017TU	" "	"	1		
C3-18	TU-I-0Zh0-460-001	" "	"	1		
C3-19	TU-I-0Zh0-460-001	" "	"	1		
C3-20	"	" "	"	1		
C3-21	"	" "	"	1		
C3-22	TU-I-0Zh0-460-001	" "	"	1		
C3-23	0Zh0-460-014TU	" KTK-1m-5 pf-I	5 pf	1	Select, 2,5-5 pf-I	
C3-24	TU-I-0Zh0-460-001	" KO-1k-22 pf-II	22 pf	1		
C3-25	TU-I-0Zh0-460-001	" KDS-1a-1000	1000 pf	1		
C3-27	0Zh0-460-014TU	" KTK-1m-27 pf	27 pf	1		

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List of Elements

Pos. Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	Ch
C3-28	0Zh0-462-011TU	Capacitor, BGM-2-400-0.01 mf	0.01 mf	1		
C3-29	"	" BGM-1-400-0.01-II	0.01 mf	1		
C3-30	"	" "	"	1		
C3-31	TU-I-0Zh0-460-001	" Kh0-1-I-1000-II	1000 pf	1		
C3-32	0Zh0-462-011TU	" BGM-2-400-0.01-II	0.01 pf	1		
C3-33	0Zh0-462-022TU	" MBGP-2-200-2x0.5-II	0.5 pf	1	together with C3-[illegible]	
C3-34	0Zh0-462-011TU	" BGM-2-400-0.01-II	0.01 pf	1		
C3-35	"	" "	"	1		
C3-36	"	" "	"	1		
C3-37	0Zh0-462-022TU	" MBGP-2-200-2x0.5-II	0.5 mf	1	together with C3-[illegible]	
C3-38	0Zh0-462-011TU	" BGM-2-400-0.01-II	0.01 mf	1		
C3-39	0Zh0-462-022TU	" MBGP-2-400-2 0.1-II	0.1 mf	1	together C3-64	
C3-40	0Zh0-462-011TU	" BGM-2-400-0.01mf	0.01 mf	1		
C3-41	"	" BGM-2-400-0.05-II	0.05 mf	1		
C3-42	"	" "	"	1		

List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note
C3-43	0Zh0-462-011TU	Capacitor, BGM-2-400-0.05-II	0.05 mf	1	
C3-44	"	" BGM-2-400-0.01-II	0.01 mf	1	
C3-45	"	" "	"	1	
C3-46	"	" "	"	1	
C3-47	0Zh0-460-014TU	" KTK-2a-L-330-II	330 pf	1	
C3-49	"	" KTK-3m-150-I	150 mf	1	
C3-50	0Zh0-462-022TU	" MBGP-2-400-2X0.1	0.1 mf	1	
C3-51	UP0-464-005TU	" KS-2-500-680-Ts-I	68- pf	1	
C3-52	0Zh0-462-022TU	" MBGP-2-400-2 0.1-II	0.1 mf	1	together with C3-5
C3-53	UP0-464-005TU	" KS-1-500-0-100-II	100 pf	1	
C3-54	0Zh0-462-011TU	" BGM-2-400-0.01-II	0.01 mf	1	
C3-55	"	" BGM-2-400-1500-II	1500 pf	1	
C3-56	"	" BGM-2-400-0.01-II	0.01 mf	1	
C3-57	UP0-464-005TU	" KS-1-500-0-200-I	200 pf	1	
C3-58	UB0-460-016TU	" KTN-1-D-100-II	100 pf	1	

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Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type		Basic Data Rated	No.	Note Ch.
C3-59	0Zh0-462-022TU	Capacitor,	MBGP-2-400-2 0.1-II	0.1 mf	1	together with C3-71
C3-60	0Zh0-462-011TU	"	BGM-2-400-3300-II	3300 pf	1	
C3-61	"	"	BGM-2-400-0.01-II	0.01 mf	1	
C3-62	UB0-460-016TU	"	KTN-1-D-100-II	0.01 mf	1	
C3-63	0Zh0-462-011TU	"	BGM-2-400-0.01-II	0.01 mf	1	
C3-64	0Zh0-462-022TU	"	MBGP-2-400-2 0.1 mf	0.1 mf	1	
C3-65	0Zh0-462-011TU	"	BGM-2-400-1500-II	1500 pf	1	
C3-66	"	"	BGM-2-400-0.01-II	0.01 mf	1	
C3-67	0Zh0-462-022TU	"	MBGP-2-200-2-II	2 mf	1	
C3-68	0Zh0-460-0.15TU	"	KTK-1-L-100-II	100 pf	1	
C3-69	0Zh0-462-011TU	"	BGM-2-400-0.01-II	0.01 mf	1	
C3-70	UP0-464-005TU	"	KS-1-500-200-II	200 pf	1	
C3-71	0Zh0-462-022TU	"	MBGP-2-400-2X0.1-II	0.1 mf	1	together with C3-59
C3-72	UP0-464-005TU	"	KS-2-500-P-680-N-I	680 pf	1	
C3-73	0Zh0-462-022TU	"	MBGP-2-200-2 0.5-II	0.5 mf	1	

List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note Ch.
C3-74	0Zh0-462-022TU	Capacitor, MBGP-2-200-2 0.5-II	0.5 μf	1	
C3-75	0Zh0-462-011TU	" BGM-2-400-0.05-II	0.05 μf	1	
C3-76	"	" "	"	1	
C3-77	UPO-464-005TU	" KS-1-500-0-100-II	100 pf	1	
C3-83	0Zh0-462-022TU	" MBGP-2-200-1-II	1 μf	1	
C3-85	0Zh0-462-011TU	" BGM-2-400-0.05-II	0.05 μf	1	
C3-86	"	" "	0.05 μf	1	
C3-87	0Zh0-462-022TU	" MBGP-2-200-2X0.05-II	0.05 μf	1	
C3-88	"	" "	"	together with C3-87	
L-3-1	AR50-2-52-000	Filament Choke	0.6 μh	1	
L-3-2	"	"	"	1	
L-3-3	"	"	"	1	
L-3-4	"	"	"	1	
L-3-5	"	"	"	1	
L-3-6	"	"	"	1	

List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type		Basic Data Rated	No.	Note
L-3-7	GI4-777-003SP	Filament, H-F-D01520 mh		20 mh	1	
L-3-8	"	"	"	"	1	
L-3-9	"	"	"	"	1	
L-3-10	"	"	"	"	1	
L3-1	ChTU-0110-355	Radio Tube	6Zh1P		1	
L3-2	"	"			"	
L3-3	ChTU0-110-455	"	6Zh2P		"	
L3-4	"	"			"	
L3-5	ChTU0-110-355	"	1Zh1P		"	
L3-6	ChTU0-110-355	"	6Zh2P		"	
L3-7	TS3-301-000TU	"	6Zh3P		"	
L3-8	TS3-301-000TU	"			"	
L3-9	ChTU01-104-55	"	6Zh2P		"	
L3-10	TS3-301-000tU-I	"	6Zh3P		"	
L3-11	ChTU01-105-55	"	6Zh1P		"	

List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	Ch.
L3-12	ChTU-011-855	Radio Tube 6Zh2P		1		
L3-13	TS3-301-000TU-1	" 6Zh3P		"		
L3-14	ChTU0110455	" 6Zh2P		"		
L3-15	ChTU0118855	" 6Zh2P		"		
L3-16	TS3-301-000TU-1	" 6Zh3P		"		
L3-17	ChTU0144055	" 6Zh5P		"		
L3-18	"	"		"		
L3-19	TS3-301-000TU-1	" 6Zh3P		1		
L3-20	"	" "		"		
L3-21	"	" "		"		
L3-22	"	" "		"		
L3-23	ChTU0110455	" 6Zh2P		"		
L3-25	"	" 6Zh2P		"		
L3-26	ChTU0131856	" 6Zh1P		"		
L3-27	ChTU0131556	" 6D6A		"		

List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	Ch.
L3-28	CHTU0131556	Radio Tube 6D6A		1		
Tr-3-1	GYa4770013SP	Transformer, H.F.		"		
Tr-3-2	"	"		"		
Tr-3-2	"	"		"		
Tr-3-3	"	"		"		
Tr-3-4	"	"		"		
Tr-3-5	"	"		"		
Tr-3-6	GYa4-710-025SP	Filament Transformer		"		
Tr-3-7	GYa4-720-006SP	Pulse Transformer		"		
Z-3-1	AR50-2-54-000	Filtering Cell		"		
Z-3-2	"	"		"		
Z-3-5	"	"		"		
L33-1	GYa2-066-012SP	Line of Delay	0.4 μsec.	"		
Sh3-1	AR50-032-012SP	Intra-cell disconnector		"		
Sh3-2	VN0364-0064TU	Plug R48PK28EN1		"		
Sh3-3	"	Socket R32PK28EN1		"		
R3-1		Relay RMUG RS4-523419D1 RS04520P2TU		"		
R3-2		"		"		
R3-3		"		"		
R3-4	1RM-3-2 sb02	Coaxial Cable Socket		"		
R3-5	"	"		"		

List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing.	Name and Type		Basic Data Rated	No.	Note
1	2	3		4	5	6
R 4-1	0Zh0-467-011TU	Resistor,	PEV-10-10 kOhm±10%	10 kOhm	1	
R 4-2	0Zh0-467-003TU	"	MLT-2-39 kOhm-P-V	39 kOhm	1	
R 4-3	0Zh0-467-003TU	"	MLT-1-39 kOhm-P-V	39 kOhm	1	
R 4-4	0Zh0-467-003TU	"	MLT-1-390 kOhm-P-V	390 kOhm	1	
R 4-5	0Zh0-467-003TU	"	MLT-1-390 kOhm-P-V	390 kOhm	1	
R 4-6	BP4-675-001SP	"	PT-1-91 kOhm±1% lw	91 kOhm	1	
R 4-7	BP4-675-001SP	"	PT-1-68 kOhm±1% lw	68 kOhm	1	
R 4-8	NRKh4-685-018SP	"	PPZ-11-10 kOhm±10%	10 kOhm	1	
R 4-9	BP4-675-001SP	"	PT-1-56 kOhm±1% lw	56 kOhm	1	
R 4-10	0Zh0-467-003TU	"	MLT-510 kOhm-P-B	510 kOhm	1	
R 4-11	0Zh0-467-003TU	"	MLT-1-39 kOhm-P-B	39 kOhm	1	
R 4-12	0Zh0-467-003TU	"	MLT-1-390 kOhm-P-B	390 kOhm	1	
R 4-13	BP4-675-001SP	"	PT-1-100 kOhm±1% lw	100 kOhm	1	
R 4-14	BP4-675-001Sp	"	PT-1-68 kOhm±1% lw	68 kOhm	1	
R 4-15	NG4-685-018SP	"	PP3-11-10 kOhm±10%	10 kOhm	1	
R 4-16	BP4-675-001SP	"	PT-1-82 kOhm±1% lw	82 kOhm	1	
R 4-17	0Zh0-467-011TU	"	PEV-10-10 kOhm±10%	10 kOhm	1	
R 4-18	0Zh0-467-003TU	"	MLT-1-39 kOhm-P-B	39 kOhm	1	

List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note
1	2	3	4	5	6
R 4-19	0Zh0-467-003TU	Resistor, MLT-1-390 kOhm-V-Ya	390 kOhm	1	
R 4-20	0Zh0-675-001SP	" PT-1-130 kOhm±1% 1w	130 kOhm	1	
R 4-21	NG4-685-018SP	" GN3-11-10 kOhm±1% 1w	10 kOhm	1	
R 4-22	BP4-675-001SP	" PT-1-91 kOhm±1% 1w	91 kOhm	1	
R 4-23	0Zh0-467-003TU	" MLT-2-39 kOhm-P-B	39 kOhm	1	
R 4-24	0Zh0-467-003TU	" " "	39 kOhm	1	
R 4-25	0Zh0-467-003TU	" MLT-1-39 kOhm-PB	39 kOhm	1	
R 4-26	0Zh0-467-003TU	" MLT-1-390 kOhm-P-B	390 kOhm	1	
R 4-27	0Zh0-467-003TU	" " "	390 kOhm	1	
R 4-28	BP4-675-001SP	" PT-1-30 kOhm±1% 1w	30 kOhm	1	
R 4-29	BP4-675-001SP	" PT-1-75 kOhm±1% 1w	75 kOhm	1	
R 4-30	BP4-675-018SP	" PP3-11-10 kOhm±1%	10 kOhm	1	
R 4-31	BP4-675-001SP	" PT-1-35 kOhm±1% 1w	35 kOhm	1	
R 4-32	0Zh0-467-003TU	" MLT-2-3.3 kOhm-I-B	3.3 kOhm	1	
R 4-33	0Zh0-467-003TU	" MLT-1-510 kOhm-P-B	510 kOhm	1	
R 4-34	0Zh0-467-003TU	" MLT-1-100 kOhm-P-B	100 kOhm	1	
R 4-35	"	" MLT-1-910 kOhm-P-B	910 kOhm	1	
R 4-36	"	" MLT-2-39 kOhm-P-B	39 kOhm	1	

List of Elements

Pos. Desig. 1	State National Standard, VTU, Normal Drawing 2	Name and Type 3		Basic Data Rated 4	No. 5	Note 6	Ch. 7
C4-1	0Zh0-462-022TU	Capacitor,	MBTP-2-600-2-II	2 µf	1		
C4-2	"	"	MBGP-2-400-0.25-II	0.25 µf	1		
C4-3	"	"	MBGP-2-400-1(50)-II	1 µf	1		
C4-4	"	"	MBGP-2-400-1.25-II	1 µf	1		
C4-5	"	"	MBGP-2-400-1-(50)-II	1µf	1		
C4-6	"	"	MBGP-2-400-2-II	2 µf	1		
C4-7	"	"	MBGP-2-400-0.25-II	0.25 µf	1		
C4-8	"	"	MBGP-2-400-1(50)-II	1 µf	1		
C4-9	"	"	MBGP-2-600-2-II	2 µf	1		
C4-10	"	"	MBGP-2-400-0.25-II	0.25 µf	1		
C4-11	0Zh0-462-011TU	"	BGM-2-400-0.01-II	0.01 µf	1		
C4-12	0Zh0-462-022TU	"	MBTP-2-200-1-II	1 µf	1		
C4-13	0Zh0-462-011TU	"	BTN-2-400-0.01-II	0.01 µf	1		
PR4-1	State National Standard 5010-53	Fuse	PK-30-2a		1		
PR4-2	"	"	PK-30-0.15a		1		
PR4-3	"	"	"		1		
PR4-4	"	"	"		1		
PR4-5	"	"	"		1		

List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	Ch[illegible]
1	2	3	4	5	6	7
L4-1	ChTU-01-107-55	Tube 6Zh1P		1		
L4-2	ChTU-01-106-55	Tube 6Zh[illegible]P		1		
L4-3	ChTU-01-107-55	Tube 6Zh1P		1		
L4-4	ChTU-01-107-55	Tube 6Zh6P		1		
L4-5	ChTU-01-106-55	Tube 6Zh6P		1		
L4-6	ChTU-01-107-55	Tube 6Zh6P		1		
L4-7	"	"		1		
L4-8	"	"		1		
L4-9	ChTU-01-10655	Tube 6Zh2P		1		
L4-10	ChTU-01-701-54	Tube SG3S		1		
D4-1	LO-354-2006TU	Plug R32PK93Sh2		1		
D4-1	TR3215-108VrTU	Germanium Diode D7-Zh		1		
D4-2	"	"		1		
D4-3	"	"		1		
D4-4	"	"		1		
D4-5	"	"		1		
D4-6	"	"		1		
D4-7	"	"		1		
D4-8	"	"		1		
D4-9	"	"		1		

List of Elements

Pos. Desig.	State National Standard, VTU, Normal Drawing	Name and Type	Basic Data Rated	No.	Note	Ch.
1	2	3	4	5	6	7
D4-10	Tr3215-108VrTU	Germanium Diode D7-Zh		1		
D4-11	"	"		1		
D4-12	"	"		1		
D4-13	"	"		1		
D4-14	"	"		1		
D4-15	"	"		1		
D4-16	"	"		1		
D4-17	"	"		1		
D4-18	"	"		1		
D4-19	"	"		1		
D4-20	"	"		1		
D4-21	"	"		1		
D4-22	"	"		1		
D4-23	"	"		1		
D4-24	"	"		1		
D4-25	"	"		1		
D4-26	"	"		1		
D4-27	"	"		1		
D4-28	"	"		1		
D4-29	"	"		1		
D4-30	"	"		1		
D4-31	"	"		1		
D4-32	"	"		1		
D4-33	"	"		1		
D4-34	"	"		1		
D4-35	"	"		1		
D4-36	"	"		1		
TR4-1	G347140160SP	Transformer		1		
TR4-2	G34714000SP	"		1		